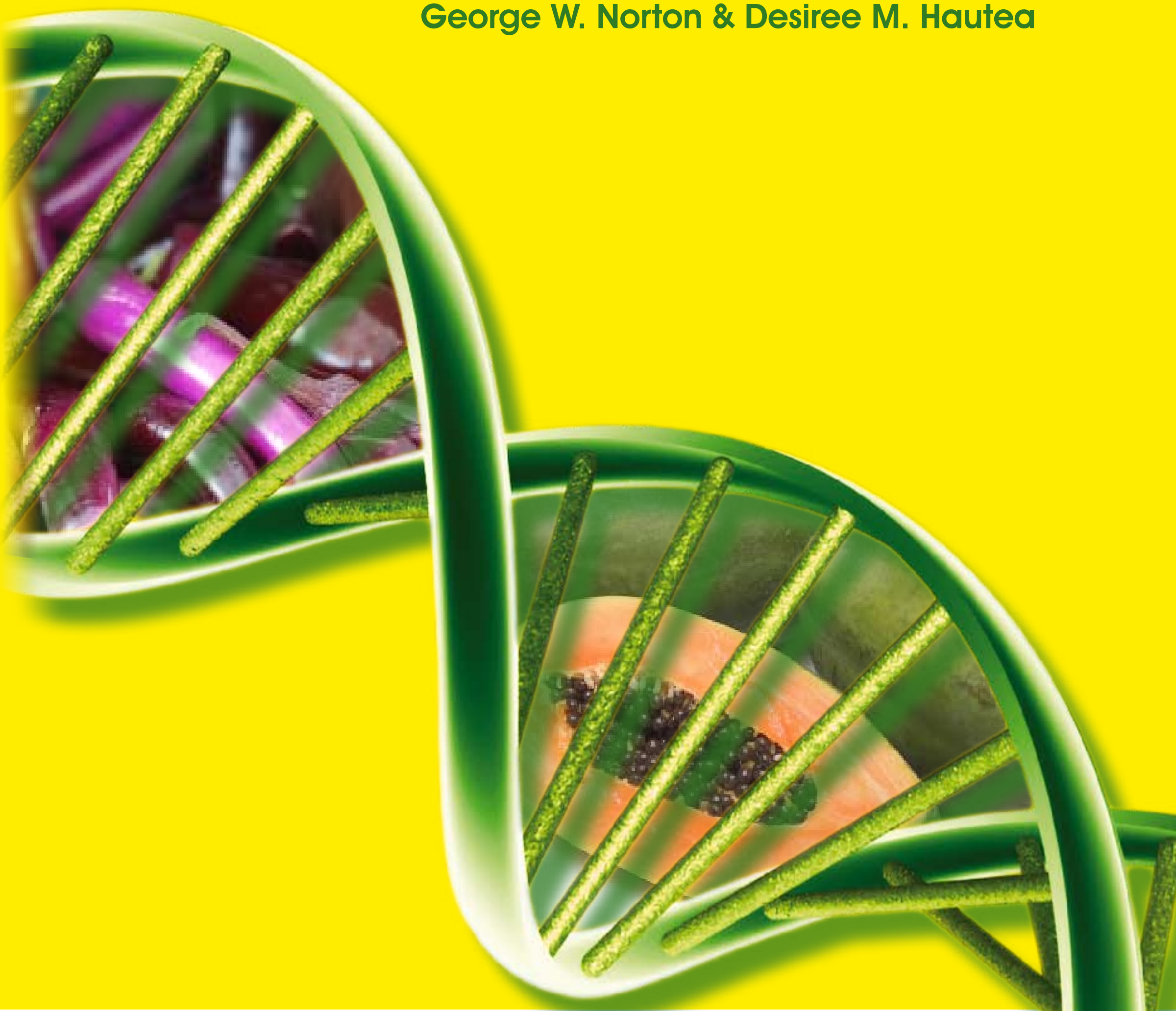
Projected Impacts of AGRICULTURAL BIOTECHNOLOGIES for FRUITS & VEGETABLES in the PHILIPPINES & INDONESIA

Edited by
George W. Norton & Desiree M. Hautea



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ABSPII focuses on the safe and effective development and commercialization of bio-engineered crops as a complement to traditional and organic agricultural approaches in developing countries. The project helps boost food security, economic growth, nutrition and environmental quality in East and West Africa, Indonesia, India, Bangladesh and the Philippines.

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Foreword

The last three decades witnessed a cascade of scientific discoveries on plant molecular biology and biochemistry that served as foundation of current biotechnologies used in improving agricultural crops. Genes coding for important agricultural traits useful to farmers and consumers were discovered, isolated and introduced into cultivated crops using modern tools of molecular biology. Plant biotechnology has emerged among the most innovative technologies in agriculture and has been increasingly used for improvement of crops which include fruits, vegetables, and plantation crops.

To date, more than 20 crops have been improved to resist important pests and diseases, tolerate drought, salinity, and extreme temperatures, and with improved nutritional and grain quality. Currently, the major biotech crops are planted in 125 million hectares in 25 countries, and directly consumed as human food or animal feed in 30 other countries. The wide and rapid adoption of biotech crops in world agriculture is compelling evidence of approval of million of farmers adopting the technology.

Tremendous benefits derived from biotech crop adoption by small and resource-poor farmers in developing countries have been documented. Thus, biotechnology and biotech crops can contribute to achieving the Millenium Development Goals set for 2015: to reduce hunger and poverty by half. Their contribution is expected to further expand in the future as more crops that are important in the developing world are given R&D attention and as more useful traits are bioengineered into the best adapted cultivars.

In South East Asia, biotechnology development and biotech crop adoption has been relatively slow due in part to various policy, socio-political and cultural issues. Since 2003, the Philippines has been the only country in the region which commercially grows biotech crops. While Indonesia was the first country in the region to commercially grow a biotech crop – *Bt* cotton in 2001, it has been discontinued for various other reasons that are unrelated to the performance of the technology.

Both countries – the only ones that have had biotech crop commercialization experience in the region, have also been the principal regional partners of Cornell University in implementing the Agricultural Biotechnology Support Project II (ABSPII).

This book, Projected Impacts of Agricultural Biotechnologies for Fruits and Vegetables in the Philippines and Indonesia presents the results of a series of studies, under the auspices of ABSPII, that assessed the potential economic impacts of bioengineered eggplant, papaya, and tomato in the Philippines; and potato and tomato in Indonesia.

I congratulate ISAAA and SEARCA for their initiative in publishing the results of these studies in the form of a book. I also congratulate the editors for their dedicated efforts in bringing out this excellent publication. It is hoped that the additional valuable information contained in the book would contribute to the stock of knowledge on biotech crops and would help serve as basis for the development, deployment and adoption of the featured biotech crops in the near future.

Emil Q. Javier
President
National Academy of Science and Technology, Philippines

9 September 2009

Preface

Adoption of crop varieties developed through modern biotechnology has grown rapidly around the world since the mid 1990s, especially in developed countries, but increasingly in developing countries as well. The Philippines for example, was one of the early adopters of genetically modified maize, *Bt* cotton is widespread in China and India among other countries, and herbicide tolerant soybeans are popular in Brazil and Argentina. The adoption of genetically modified food crops, however, is still relatively limited, including in Southeast Asia. In some cases, this limited adoption is due to lack of research, in others lack of adequate regulatory systems being in place, and in others a fear that commercial acceptance will be limited due to perceived risks exceeding benefits.

Beginning in 2003, the Agricultural Biotechnology Project II (ABSPII) led by Cornell University and funded by the United States Agency for International Development (USAID), undertook a project to address important constraints to agricultural production through biotechnology. The focus was on a set of crops and constraints that were identified by stakeholders as being important but that were largely ignored by the private sector. For Southeast Asia, the target countries were the Philippines and Indonesia, and target crops were papaya, eggplant, potato, and tomato. A multi-disciplinary and multi-institutional program was developed that addressed all aspects of developing and commercializing genetically modified organisms to address the production constraints. One aspect of the program was to evaluate the potential economic benefits of the GMOs, taking into account regulatory as well as research costs. This book provides the results of the various economic studies. The results are very encouraging in terms of the potential for significant economic benefits. They also highlight the importance of rapid deployment of the improved crop varieties.

During these studies, conducted by economists from the Philippines, Indonesia, and Virginia Tech in the United States, information was obtained from a number of scientists and other experts and the authors gratefully acknowledge their assistance. We especially would like to thank Dr. Liborio S. Cabanilla (College of Economics and Management, University of the Philippines Los Baños) and Dr. Albert P. Aquino (Socioeconomics Research Division, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development) for their extensive reviews of the early draft of the book. The tremendous editorial help from Roberta V. Gerpacio and Panfilo G. de Guzman is very gratefully acknowledged and the support from Dr. Randy A. Hautea at ISAAA. We would also like to thank the assistance of Dr. Rhodora R. Aldemita and ISAAA staff in the final stage of the preparation of the book. Funding for the studies was provided by USAID through the ABSPII project and by ISAAA.

George W. Norton
Blacksburg, Virginia, USA

Desiree M. Hautea
Los Baños, Laguna, Philippines

14 September 2009

Message from ABSPII

ABSPII is a USAID-funded consortium of public and private sector institutions that work with national research organizations, agricultural universities and private biotechnology companies to conduct research and development activities focusing on crops that are important to resource-poor farmers and consumers in developing countries. Our consortium, led by Cornell University, support projects designed to complement national and regional efforts to develop and commercialize bioengineered crops in Africa and Asia. ABSPII projects are implemented within the context of a 'product commercialization package' (PCP) approach that integrates all elements of research, development and commercialization processes.

In 2003, representatives from private and public sector stakeholder groups from Indonesia and the Philippines were consulted to identify priority products where investment in biotechnology R&D can be supported. Under this priority setting exercise, prospective products selected in the Philippines were fruit and shoot borer resistant (*Bt*) eggplant, ring spot virus resistant (PRSV-R) papaya, and multiple virus resistant (MVR) tomato. Late blight resistant (LBR) potato and MVR tomato were selected in Indonesia. It is envisioned that investment in these products would help boost food security, agricultural productivity and environmental quality in both countries.

One aspect of the PCP approach to biotech product development espoused by ABSPII is to evaluate the potential benefits of the product to ensure that investments are focused only in products with the greatest potential to help resource-poor farmers and consumers in partner countries. This book provides encouraging information on the potential benefits of the featured biotech products. Study results clearly indicate significant benefits can be derived from biotech products in terms of yield advantage, reduced pesticide use, increased income and improved environmental quality.

It is hoped that valuable information contained in the book will form the basis for making informed decisions in moving the featured biotech products to commercialization stage as rapidly as possible.

Estrella F. Alabastro
Chairman, ABSPII Advisory Board
and *Secretary*, Department of Science and Technology, Philippines

16 September 2009

Chapter 1

Introduction and Overview of ABSPII Supported Bioengineered Crops in the Philippines and Indonesia

D.M. Hautea and G.W. Norton

Introduction

Modern biotechnology is a relatively young field and the public is sometimes wary of bioengineered [also known as transgenic or genetically modified (GM)] crops that may pose perceived yet unknown risks for what could be significant but are still undocumented benefits. Without adequate information on benefits and costs to help inform the debate, potentially useful technologies are lumped together with potentially disadvantageous ones, and acceptance or approvals for important technologies may be delayed. Helping to inform that debate requires economic analysis of the level and distribution of benefits and costs of transgenic crops, and a concerted effort to provide this information to the public.

Economic impact assessments of improved technologies are often conducted after the technologies have been released and the resulting products adopted. While such *ex-post* assessments are useful for documenting benefits from the research investments, equally important are assessments of the potential benefits of technologies before they are released and adopted. These *ex-ante* assessments can provide information to help guide investment decisions of various stakeholders and to justify continued funding for on-going research programs. In the case of biotechnologies, they can also indicate the economic impacts of delays in regulatory approval and commercial use of the products.

This book presents the results of a series of *ex-ante* impact studies to assess potential economic impacts of bioengineered crops, namely: fruit and shoot borer-resistant (FSBR) eggplant (or *Bt* eggplant), papaya ring spot virus (PRSV) resistant papaya, and multiple-virus resistant tomato (MVR tomato) in the Philippines; and late blight-resistant potato (LBR potato), potato tuber moth-resistant potato (PTM or *Bt* potato), and multiple-virus resistant tomato (MVR tomato) in Indonesia. The studies, conducted from 2004 to 2006 with support from the Agricultural Biotechnology Support Project II (ABSPII), the International Service for the Acquisition of Agri-biotech Applications (ISAAA), and the International Potato Center (CIP, for Chapter 7), aimed in general to provide project leaders, funding agencies, policy makers, and other stakeholders with information to help them make rational resource allocation decisions and choices in supporting bioengineered crops development in Southeast Asia. ABSPII has completed the first five years conducting R&D activities in the Philippines and Indonesia to develop commercial bioengineered crop products that can help solve major pests and other problems in selected target commodities and countries. This book summarizes the projected level and distribution of costs and benefits associated with those activities and products, including the anticipated value of potential environmental impacts.

This chapter presents a brief overview of the ABSPII strategy, the bioengineered product packages and regulatory structures of the Philippines and Indonesia, while the basic methods employed in the studies are described in Chapter 2. Chapters 3 to 8 present the projected direct economic impacts of biotechnologies for specific commodities and countries, while Chapters 9 and 10 present detailed assessments of the regulatory costs involved in bringing the products to market, and the implications of regulatory delays in commercial approval and use of the products. Chapter 11 provides the projected value of the potential environmental effects and Chapter 12 presents the summary and conclusions.

Overview of ABSPII Supported Bioengineered Crops in the Philippines and Indonesia

In many developing countries including the Philippines and Indonesia, concerns on food security, poverty alleviation and environmental sustainability are putting more pressure on people and institutions to find alternative ways to achieve higher agricultural productivity. Because conventional plant breeding techniques cannot always address production and productivity constraints, modern biotechnology has been identified as a viable technological supplement to produce commercially important crops that can contribute greatly to agricultural productivity and environmental sustainability.

ABSPII Product Driven Strategy

The R&D activities for the products described in Chapters 3 to 11 were carried out within the context of the ABSPII product-driven strategy. ABSPII is a cooperative agreement between USAID and the Cornell University-led consortium of public and private sector institutions designed to complement national and regional efforts to develop and commercialize bioengineered crops in developing countries in Asia and Africa (http://www.absp2.cornell.edu). The ABSPII strategy emphasizes the identification and delivery of products that are likely to have significant positive socioeconomic impact, relevant to local needs, and which can be brought quickly to the stage of field trials to catalyze the regulatory process and eventually for possible commercial approval. To assure relevance and to avoid investing in products that are unlikely to be adopted, priority setting consultations were conducted with local stakeholders as a first step. These consultations were followed by a feasibility assessment which considered all of the key technical and non-technical components that in turn affect farm-level acceptability and productivity and balance country-specific, regional, and even global needs. ABSPII emphasizes supporting on-going R&D activities of local public sector institutions. Whenever possible, ABSPII created public-private partnerships to help leverage both public and private funding sources to help absorb development costs and provide broader distribution channels.

The prospective product is implemented within the context of a ‘product commercialization package’ (PCP) approach (Figure 1) that integrates all elements of the research, development and commercialization processes. The main elements of each PCP include: (i) technology development; (ii) policy-related issues such as licensing the intellectual and technical properties associated with the product, as well as applying for and obtaining regulatory approval from the relevant national authorities; (iii) communicating public information to producers and consumers about the benefits, risks and correct management of these new products; and (iv) establishing, or verifying, the existence of marketing and distribution mechanisms to provide farmers access to planting materials (Gregory et al., 2008).

In 2003, ABSPII conducted priority setting workshops in the Philippines and Indonesia in consultation with local representatives of public and private sector stakeholder groups. More than 20 types of biotechnology research on-going in 2003 were presented, majority of which were in very early research

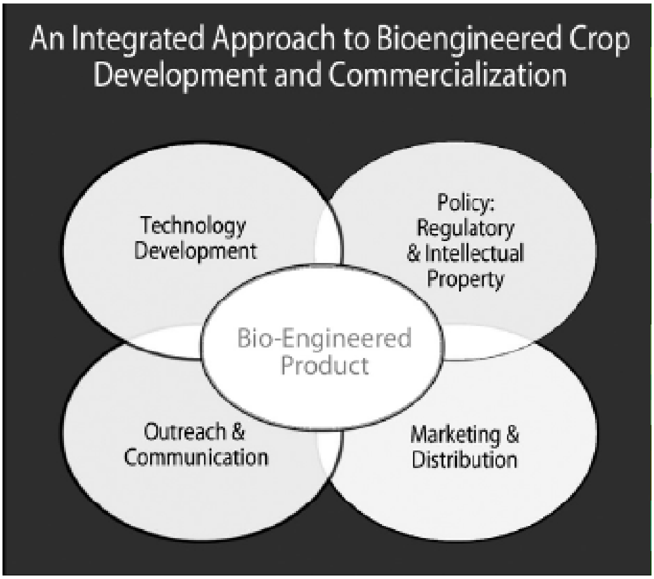

Figure 1. Main elements of an integrated product-driven approach for development and delivery of bioengineered crops (Source: ABSPII)

stage. The choices were narrowed down to two to three potential products to leverage opportunities and resources available between the two countries and in other countries supported by ABSPII and other institutions. The prospective products selected in the Philippines were *Bt* eggplant (together with India and Bangladesh), PRSV-resistant papaya and MVR tomato. LBR potato (together with India and Bangladesh) and MVR tomato were selected for Indonesia. *Bt* potato previously supported under ABSP was continued in South Africa with potential for spill-over in Indonesia.

Regulation of Bioengineered Crops in the Philippines and Indonesia

While recognizing the enormous potential benefits of modern biotechnology, research, product development and market release of bioengineered crops in many countries including the Philippines and Indonesia are strictly regulated. Regulatory systems for bioengineered crops were put in place in both countries to ensure safety to human health and the environment while providing economic benefit to resource-poor farmers and consumers. In addition to agronomic performance, science-based environmental and food safety risk assessments are performed at various stages of research and product development, as legally required by the respective national governments.

In the Philippines, the regulatory system is well established and functional since 1990 and continues to evolve over time.The Philippines made history in 2002 as the first Asian country to approve a GM feed crop, corn, for commercial cultivation and continued on to become a "biotech mega country"[1] to this date (James, 2008). Regulation of bioengineered crops is jointly administered under a coordinated framework by the National Committee on Biosafety of the Philippines (NCBP) and the Department of Agriculture Bureau of Plant Industry (DA-BPI) under the authority of Executive Order (EO) 430 of 1990 (superceded by EO 514 of 2007) issued by the Office of the President of the Philippines and DA Administrative Order No. 8 Series of 2002 (DA-AO 8) based on the Plant Quarantine Act.

The NCBP, a multi-agency, multi-disciplinary body, acts as the nodal agency that sets policies and coordinates all conduct of activities and products of modern biotechnology in the country. Through the NCBP-Biotech Committee (NCBP-BC) it evaluates and approves all R&D activities in the laboratory, greenhouse, screenhouse and confined fields. DA-BPI meanwhile regulates the importation, multi-location field trials and commercial (farm) cultivation of all plants and plant products derived from modern biotechnology. Risk assessments under DA-BPI is conducted by the BPI-Biotechnology Core Team (BPI-BCT) and the Science and Technology Review Panel (STRP) consisting of independent technical experts in various science disciplines. When necessary, risk assessments are conducted in cooperation with other statutory agencies like the Fertilizer and Pesticide Authority (FPA) and the Bureau of Animal Industry (BAI). An Institutional Biosafety Committee (IBC) established by the applicant's institution in each trial site assists both the NCBP and DA-BPI in evaluating and monitoring activities during the conduct of the trials. Detailed procedures and application forms for importation, field trials, propagation, and direct use for food and feed can be downloaded from http://www.biotech.da.gov.ph.

The regulatory system in Indonesia was established as early as 1993 with the issuance of guidelines for genetic engineering research. Over time, it evolved to meet technological advances and regulatory needs. In 1997, the Ministry of Agriculture issued the biosafety regulation for release of GM crops, followed by the Joint Ministerial decree of 1999 to include the guidelines on food safety. The current legislative authority to regulate biotechnology in Indonesia is embodied in Government Regulation Number 21 of 2005 concerning the Biosafety of Living Modified Products.

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[1] A country is considered "biotech mega country" when commercial plantings of biotech crops reach 50,000 ha., or more, in a particular year.

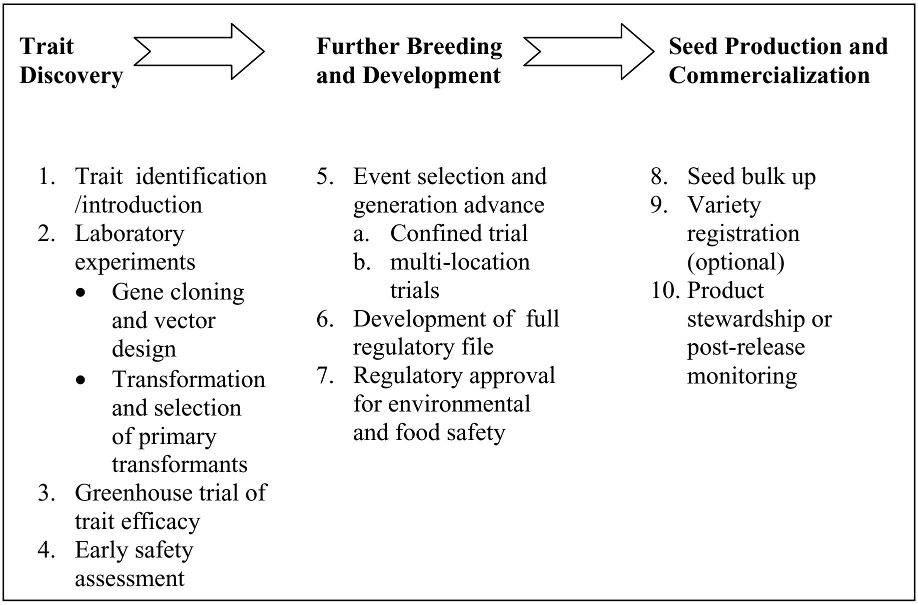
Although the legislative authority in Indonesia is different from that in the Philippines, their biosafety framework, guidelines and requirements for the conduct of genetic engineering activities and assessing risks for environmental and market release of products of modern biotechnology are similar. Created and expanded under the 1999 Joint Ministerial decrees, the national Biosafety and Food Safety Committee (BFSC) of Indonesia, supported by the Biosafety and Food Safety Technical Team (BSFTT), continues to administer the conduct of biosafety regulation in the country including the approval for release of GM crops.

Indonesia has approved the conduct of laboratory, greenhouse and field trials of several crops (Karossi, 2005) including the field trial of *Bt* potato in 1997 and the commercial release of *Bt* cotton in 2001 in South Sulawesi. However, due to various reasons unrelated to the agronomic performance of the product, the technology developer withdrew *Bt* cotton from commercial cultivation in 2002. More information on biosafety regulation and mechanism for release of GM crops in Indonesia can be found in the Indonesia Biosafety Clearing House (http://www.indonesiabch.org).

Status of Development of ABSPII Supported Bioengineered Crops in the Philippines and Indonesia

Figure 2 presents a slightly modified version of Gregory et al.'s (2008) illustrated typical steps to follow in the development and delivery of bioengineered crops. Steps 1, 3, 5b, 8 and 9 are similar to breeding a new crop variety. After testing and evaluating agronomic performance, releasing new varieties in the Philippines and Indonesia are quite straightforward through their national seed certification and variety registration agencies. Because GM crop actvities and products are strictly regulated in both countries, other steps are required, adding costs and complexity to research activities, product development and commercial release.

ABSPII support to R&D work on bioengineered crops in the Philippines and Indonesia started in 2003 except for PRSV-resistant papaya, which was initiated by the Philippine Department of Science and Technology (DOST) in 2000. Complying with the prevailing regulatory system in their own countries, the University of the Philippines Los Baños (UPLB) and the Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (ICABIOGARD) obtained permits to import transgenic events from Malaysia (PRSV-resistant papaya), India (*Bt* eggplant), the USA (LBR potato) and AVRDC-The World Vegetable Center (MVR tomato). The results of various experiments were submitted to the competent authorities at every stage of the research and development of the prospective products.



Trait Discovery → **Further Breeding and Development** → **Seed Production and Commercialization**

1. Trait identification /introduction
2. Laboratory experiments
   - Gene cloning and vector design
   - Transformation and selection of primary transformants
3. Greenhouse trial of trait efficacy
4. Early safety assessment

5. Event selection and generation advance
   a. Confined trial
   b. multi-location trials
6. Development of full regulatory file
7. Regulatory approval for environmental and food safety

8. Seed bulk up
9. Variety registration (optional)
10. Product stewardship or post-release monitoring

Figure 2. Stages in research-development-delivery process of bioengineered crops. (Source: Adapted and modified from Gregory et al., 2008.)

The significant steps made in the development and regulation of *Bt* eggplant, PRSV-resistant papaya, LBR potato and MVR tomato in the Philippines and Indonesia are summarized in Tables 1a and 1b. The information provided also indicates the time taken in completing different studies including the submission of application, importation, laboratory experiments, greenhouse and confined field trials, biosafety studies and application for multi-location field trials for agronomic evaluation, where applicable.

After the first five years of ABSPII implementation, R&D activities for the PRSV-resistant papaya and *Bt* eggplant have significantly advanced (reached field trial stage) and were continued in the Philippines. Additional support were provided which enabled the conduct of further studies presented in Chapters 9 to 11. A proposal was submitted to the Philippine government to continue the MVR tomato work. ABSPII financial support to the Indonesian PCPs and the MVR tomato in the Philippines were discontinued after 2006 due to budget constraints. At that time, LBR potato has reached the confined field trial stage. Funding to continue the LBR potato product is currently being provided by the Indonesian government. ABSPII continues to provide technical and intellectual property/technology transfer (IP/TT) support to the LBR potato project in Indonesia.

Table 1a. Significant steps in the development and regulation of ABSPII supported bioengineered crops in the Philippines

Development stage	Time period	Regulatory requirements/approval	Regulatory agency
PRSV-resistant papaya			
Trait discovery	2000-2003	• Import permit for transgenic event issued by BPI and importation of transformed cultures from MARDI, Malaysia completed • Laboratory and greenhouse contained trial proposals approved and completed	IBC, NCBP IBC, NCBP BPI
Further breeding and development	2004-2009	• Greenhouse results and molecular data submitted • Proposals for confined trials 1 and 2 approved and completed • Proposal for verification trial of efficacy and additional molecular data approved (activities on-going)	IBC, NCBP
FSB-resistant or *Bt* eggplant			
Trait discovery	2003-2004	• Import permit for transgenic event issued by BPI • Laboratory and greenhouse contained trial proposals approved	IBC, NCBP, BPI
	2006	• Importation of BC seeds completed	IBC, NCBP, BPI
Further breeding and development	2006-2007	• Backcrossing, greenhouse trials and laboratory studies including biosafety studies completed	IBC, NCBP
	2007-2009	• Contained trial results and application for confined trial submitted • Confined trial including biosafety studies completed • Certificate of completion of contained/confined trial issued • Line purification and hybrid development	IBC, NCBP
	2009	• Application for multi-location field trial submitted (pending approval)	IBC, BPI

Development stage	Time period	Regulatory requirements/approval	Regulatory agency
MVR tomato			
Trait discovery	2004-	• Import permit for transgenic event issued by BPI • Laboratory and greenhouse contained trial proposals approved	IBC, NCBP
	2005-2006	• Importation of BC seeds completed • Greenhouse and laboratory studies completed	IBC, NCBP

Table 1b. Significant steps in the development and regulation of ABSPII supported bioengineered crops in Indonesia

Development stage	Time period	Regulatory requirements/Approval	Regulatory agency
LBR potato			
Trait discovery	2004	• Import permit for transgenic event issued and importation completed	BFSTT
	2004-2005	• Agronomic performance test of transgenic potato lines in the Biosafety Containment Facility • Molecular testing	BFSTT
Futher breeding and development	2005-2006	• Application for biosafety testing • Biosafety evaluation (questioner and documents) by BFSTT • Isolated field test (IFT) of transgenic potato selected lines for one season • Evaluation of the results of IFT by BFSTT	BSFTT
MVR tomato			
Trait discovery	2004-2005	• Import permit for transgenic event issued and importation completed	BSFTT
	2005-2006	• Agronomic performance test of transgenic tomato lines in the Biosafety Containment Facility • Molecular testing	BSFTT

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Chapter 2

Methodology

G.W. Norton

Introduction

Economic assessments of improved technologies are often conducted after the technologies have been released and the resulting products adopted. Such assessments are useful for documenting benefits from the research investments, but equally important are assessments of the potential benefits of technologies before they are released and adopted. These assessments can provide information to help guide investment decisions and to justify continued funding for on-going research programs. In the case of biotechnologies, they can also indicate the economic impacts of delays in the regulatory program.

Methods

The basic economic impact analyses for each technology/crop in Chapters 3 to 8 to project benefits of the technology included a consistent framework with the following steps.

(a) Review of data on crop losses and cropping practices

Existing published and other data on crop losses and cropping practices to manage the problems targeted by the transformation were reviewed for the crops and countries under study. Data were obtained for the key production areas in Indonesia and the Philippines where the crops are grown.

(b) Partial budgeting with and without the transgenic technologies

Partial budget analysis is an evaluation technique for assessing the incremental effects of technological change at the field level. It examines how adopting a new technology affects profitability by comparing the existing situation with the alternative method. It explores the net effects of factors that increase returns and reduce costs versus those that reduce returns and increase costs. The net change between positive and negative economic effects is an estimate of the net effect of the technological innovation.

For the studies in this book, field trial or experimental data on yields and input costs were gathered for the transgenic and alternative technologies, and expert opinions of farmers, biological scientists, and other industry stakeholders were solicited (see Appendix 1 for sample survey instruments). Published data for the most recent four-year period on prices, production, and national trade of the target crops were collected, and expert decisions were made on the nature of their markets (e.g., closed, small-open, or large-open economy). Partial budgets with expected per-hectare cost and yield changes with and without the transgenic technologies were calculated for each target crop and technology for the selected regions in the countries studied.

(c) Gathering information on time and costs required to complete the research and meet regulatory hurdles

The scientists conducting the research and others involved in the regulatory process were interviewed to help assess the time, cost, and regulatory hurdles. The steps in the regulatory process were determined from written documents, their history of being applied to *Bt* maize in the Philippines were considered, and information on the current research and regulatory status for each crop was obtained.

(d) Assessing the rate and timing of adoption of transgenic varieties

The percentage and timing of farmer adoption of the transgenic varieties by region within the country were projected based on secondary information on agroecological, socioeconomic, variety considerations and other factors, including information on where the targeted problem is most severe. Farmer adoption of previous technologies and expert opinion on factors such as research lag, lag due to the regulatory process, and projections on how the transgenic seeds will be commercialized were considered in estimating the likely timing and rate of farmer adoption of transgenic varieties.

(e) Conducting an ex-ante economic surplus analysis

The most common approach for analyzing the market level welfare implications of a given technological innovation in a partial equilibrium framework is economic surplus analysis. A cost-reducing or yield-enhancing effect of adopting new technologies is a shift in the supply curve, increasing the quantity produced and potentially reducing output price. If output price is reduced, consumers gain because they can consume more of the good at a lower price. Farmers may gain or lose depending on whether or not their lower cost per unit of production offsets the effect of the lower output price. Therefore, the net welfare effect on producers may be positive or negative depending on supply and demand elasticities.

The analysis adopted in these studies follows previous *ex-ante* approaches already described in many studies (Qaim and von Braun, 1998; Qaim, 1999; Babu and Rhoe, 2003; Lemieux and Wohlgenant, 1989). Estimates of price elasticities of supply and demand were obtained for each target crop based on published estimates or on economic theory. Scientists were asked to assess the probability of achieving technical success with the research. The budget information, secondary data, and farmer adoption information were combined in an economic surplus model to assess the total economic benefits and their regional distribution within each country, as well as to the seed sector, producers and consumers. The costs of the research and product development including meeting regulatory hurdles were included along with the benefits in a benefit-cost analysis of the public investment.

This book addresses two major market situations: first, a closed economy producer country (no trade), and second, an open economy in which the producing country cannot affect the product's world price even though the country trades it (a small open economy).

Economic Surplus – Closed Economy (No Trade)

As described in Norton et al. (2005), when widespread adoption of a new technology occurs across large areas, changes in crop prices, cropping patterns, producer profits, and societal welfare can occur. These changes arise because costs differ and because supplies may increase, affecting prices for producers and consumers. Figure 1 illustrates such changes. S_0 represents the commodity/crop supply curve before the adoption of a new technology (in this case, GMO), and D represents the demand curve. The initial equilibrium price and quantity are P_0 and Q_0, respectively. Suppose the new technology leads to a savings of R in the average and marginal cost of production, reflected in a downward shift of the supply curve to S_1. This shift leads to an increase in production and consumption to Q_1 (change in quantity, $\triangle Q = Q_1 - Q_0$) and

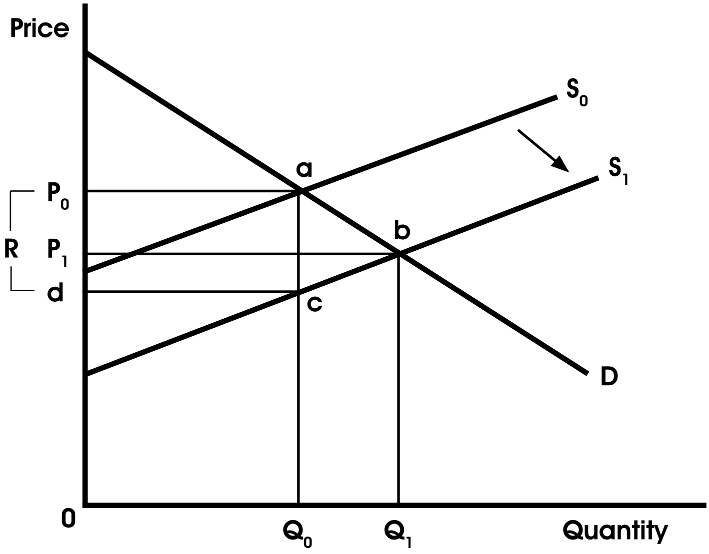

Figure 1. GMO benefits measured as changes in economic surplus in a closed economy scenario

the market price falls to P_1 (by change in price, $\triangle P = P_0 - P_1$). Consumers are better off because they can consume more of the commodity at a lower price. They benefit from the lower price by an amount equal to their cost saving on the original quantity (Q_0 x $\triangle P$) plus their net benefits from the increase in consumption. Total consumer benefits are represented by the area P_0abP_1 in Figure 1.

Meanwhile, although they may receive a lower price per unit, producers are better off too, because their costs have fallen by R per unit, an amount greater than the fall in price. Producers gain the increase in profits on the original quantity (Q_0 x (R - $\triangle P$)) plus the profits earned on the additional output, for a total producer gain of P_1bcd. Total benefits of the new technology are obtained as the sum of producer benefits and consumer benefits, or the area represented by P_0abcd in Figure 1.

The distribution of benefits between producers and consumers depends on the size of the fall in price ($\triangle P$) relative to the fall in costs (R) and on the nature of the supply shift. For example, if a commodity is traded and production in the area producing the commodity has little effect on price, most of the benefits would accrue to producers. If the supply curve shifts in more of a pivotal fashion as opposed to a parallel fashion as illustrated in Figure 1, the benefits to producers would be reduced. Formulas for calculating consumer and producer gains for a variety of market situations are found in Alston et al. (1995). For example in Figure 1, which assumes no trade (i.e., closed economy), the total economic benefits to producers and consumers is computed as KP_0Q_0 $(1 + 0.5Ze)$, where: K = the proportionate cost change, P_0 = initial price, Q_0 = initial quantity, Z = Ke/(e + n), e = the supply elasticity, and n = the demand elasticity. Other formulas would be appropriate for other market situations.

Economic Surplus – Small Open Economy (with Trade)

Biotechnology benefits can also be modeled using a small open economy framework wherein the producer country is small relative to the global trade and cannot significantly influence the international price. In equilibrium, domestic production is represented by Q_2 and consumption by Q_1 at the given world market price of P_w (Figure 2). The amount exported is represented by the difference between Q_2 and Q_1. With a new technology to improve crop production (in this case, GMOs), the parallel downward shift of the supply curve from S_0 to S_1 increases production to Q_3 thereby increasing exports by the amount $Q_3 - Q_2$. The economic surplus gained is represented by the change in producer surplus given by the area abcd.

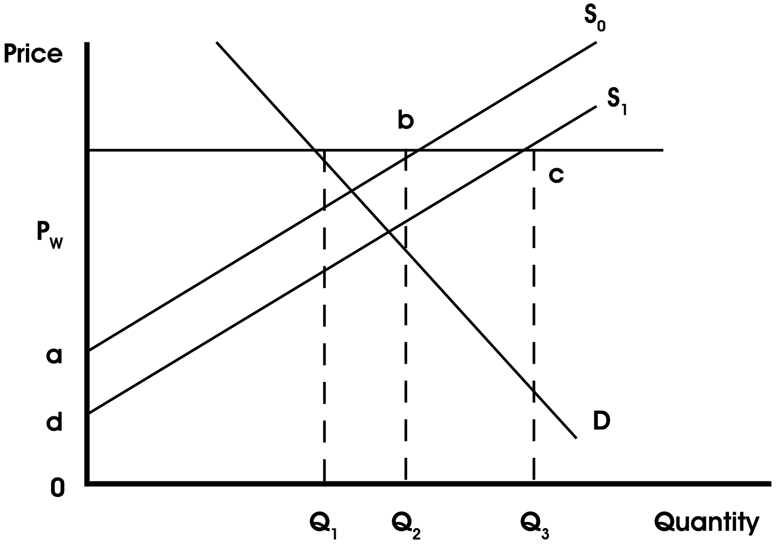

Figure 2. GMO benefits measured as changes in economic surplus in a small open economy scenario

The proportionate downward shift in the supply curve due to a (GM crop) technology is represented by K_t expressed as (Alston et al., 1995):

$$K_t = [\, E(Y)/e - E(C)/(1 + E(Y)) \,]\, \rho A_t\, (1- \delta_t)$$

where E(Y) is the expected proportionate yield change per hectare presuming research is successful and adopted; e is the crop's supply elasticity; E(C) is the proportionate change in input costs per hectare; ρ is the probability of research success; A_t is the rate of adoption; and δ_t is the rate of annual depreciation of the technology.

For the small open economy, the technology benefit from a given K shift of the supply curve is given as:

$$\triangle PS = \triangle TES = P_W Q_O K\, (1 + 0.5K\varepsilon)$$

where △PS is the change in producer surplus; △TES is the change in total economic surplus which is simply equal to the producer surplus.

The key parameters in quantifying the impact of GM crops are supply and demand elasticities, decrease in per unit production cost, the crop's world prices, and the increase in supply due to a reduction in production costs. The potential GM crop technology effects at the farm level on income and production costs are analyzed by comparing farm budgets using secondary data. A partial budget approach was employed to estimate changes in net income, and determine the economic advantage of the GM crop technology.

Once changes in economic surplus are calculated or projected over time, benefit-cost analysis of a new technology can be completed in which net present values, internal rates of return, or benefit-cost ratios are calculated. The benefits are the change in total economic surplus calculated for each year, and the costs are the public expenditures on the research and regulatory process relating to the new technology. The primary purpose of the benefit-cost analysis is to take into account the fact that benefits and costs of a new technology need to be discounted, because the sooner they occur the more they are worth. In this book, the net present value (NPV) of discounted benefits and costs of transgenic crops can be calculated as follows:

$$NPV = \sum_{t=1}^{T} \frac{R_t - C_t}{(1+i)^t}$$

where: R_t = the returns or benefits in year t, or the change in economic surplus;

C_t = the cost in year t (e.g., that of the research and regulatory costs); and

i = the discount rate (in most cases assumed to be 5% in this study)

Economic surplus estimates and net present values for this study were calculated using MSExcel spreadsheets.

Chapters 3 to 8 used this standardized set of methods to evaluate the basic economic *ex-ante* impacts (benefits and costs) of transgenic crops in Indonesia and the Philippines. These *ex-ante* assessments are then followed by specialized analyses of regulatory and environmental benefits and costs in Chapters 9 to 11. Methods for those analyses are described in the respective chapters.

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Appendix 1. Sample Questionnaire

Focus Group Discussions (FGDs)

Individual/Group/Association ________________ Facilitator ____________________

Part I. Individual information: (*to be asked from individual farmers in the group*)

Name: ____________________________ Location: ____________________________
Type of land tenure: ________________
Education: __________________________
Years in farming: ____________________
Farm area: ______________ (ha)

1. What is your current pest management practice to control the (pest/disease)?

2. Pest management practices (Fill in table below)

Control method	**Frequency (per cropping season)**	**Quantity**	**Remarks (e.g., brand names)**
Chemicals			
Insecticides			
Fungicides			
Others (specify)			
Biological			
Botanical			
Others (specify)			

3. Production cost structure

Cost component	**Quantity**	**Price per unit**
Seeds/planting materials		
Fertilizer		
Pesticides		
Labor		
Other		
Total production cost		

Part 2. Group discussion *(to be asked from the group)*

4. What was your yield per hectare (of crop) last year? ______________ and your average over the last five years? ______________

5. What was your average annual crop loss (%) due to (pest/disease) last year? ____________ % and over the last five years? ____________ %

6. What are the preferred (crop) varieties in your area? ____________

7. What is/are your source/s of seeds/planting materials? ____________

8. What are your market outlets? (please check √)
   a. traders ____________
   b. direct selling ____________
   c. contract growing ____________

Scientist Questionnaire

Respondent

Name: ____________
Position: ____________
Specialization: ____________
Education: ____________
Years of experience on the crop: ______

Interviewer

Name: ____________
Date: ____________

1. What will be the most likely (lowest, highest) expected yield change (%) per hectare if the (biotech crop) to address (pest/disease) is developed and adopted (for those farmers who adopt it in the region)?

Yield Gain (%)		
Lowest	**Most Likely**	**Highest**

2. What percent of total variable costs is currently represented by each variable input (hired labor, pest control, fertilizer, etc.) What is your estimate of the percent change in cost (per hectare) (if any) for each of the inputs if the biotech crop is adopted?

Region:			
Input	**Current cost share**	**Most likely cost change**	
		Decrease, increase, or no change	**Percent change**
Variable (USD/ha) Hired labor Fertilizer Pesticides Seeds Marketing Other			

3. What is the probability (percent chance) of biotech research developing a solution with a commercially acceptable level of effectiveness against the (pest/disease) control? ____________ %

4. How many years will it take to complete the technology development and to meet the various regulatory requirements?

Year	1	2	3	4	5	6	7	8	9	10	...
Technology development											
Regulatory											
Contained											
Limited field trial											
Multi-location field trial											
Food safety assessment											
Apply for commercialization											

5. What are the expected costs involved in developing the technology and meeting the regulatory requirements?

	Cost (USD)										
Technology development											
Regulatory											
Contained											
Limited field trial											
Multi-location field trial											
Food safety assessment											
Apply for commercialization											
Year	1	2	3	4	5	6	7	8	9	10	...

6. Which variety do you intend to put this technology? (encircle answer(s))

Particular	Choice		Remarks
Variety type	hybrid	Saved seeds/OP	
Variety source	public	private	
Variety use	fresh	processed	
Target market	domestic	export	

7. What are the expected unintended environmental effects? (check (√) if a concern)
   a. gene flow ____________
   b. reduced biodiversity ____________
   c. harms non-target organisms ____________
   d. others (specify) ____________

Industry Expert Questionnaire

Respondent **Interviewer**

Name: ________________________ Name: ________________________
Occupation: ____________________ Date: ________________________
Institutional affiliation (if any): ____
Years of experience on the crop: ______

1. What was the average annual crop loss (%) due to (pest/disease) last year? ______ and in the last five years? ______

2. What are the preferred varieties in your area? ____________________________

3. What are the main sources of seed? ____________________________________

4. How many years will it take to complete the technology development and to meet the various regulatory requirements?

Year	1	2	3	4	5	6	7	8	9	10	...
Technology development											
Regulatory											
Contained											
Limited field trial											
Multi-location field trial											
Food safety assessment											
Apply for commercialization											

5. What are the chances (%) that the product will pass the regulatory requirements and be commercialized? ______ %

6. What is the maximum percentage of crop area expected to be covered by the biotech crop? ______ % How many years will it take to reach that maximum once the crop is commercially released? ______

7. What are the expected costs involved in developing the technology and meeting the regulatory requirements?

Cost (USD)											
Technology development											
Regulatory											
Contained											
Limited field trial											
Multi-location field trial											
Food safety assessment											
Apply for commercialization											
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**...**

8. Do you expect an increase (decrease) in area devoted to the commodity over the next 10 years? If so, by what percent per year?

Region	**Increase, no change or decrease**	**Percent change per year**

Chapter 3

Costs and Benefits of Bioengineered Papaya with Resistance to Papaya Ring Spot Virus in the Philippines

J.M. Yorobe, Jr.

Introduction

Several transgenic technologies including the papaya ring spot virus (PRSV) resistant technology are currently under regulatory review in the Philippines. While all such technologies are required to undergo government regulatory protocols to ensure their health and environmental safety, the protocols do not require but may consider the potential economic effects of transgenic technologies prior to commercial release. To contribute to the emerging literature, this study examines *a priori* the potential economic advantages of the proposed PRSV-resistant papaya variety over PRSV-susceptible varieties in the Philippines.

In terms of area planted in 2000, papaya ranks sixth in the Philippines among fruit crops. The country contributes a little over 1 percent of global papaya production, with Brazil and Mexico accounting for 30 percent. Average yield of papaya in the Philippines is about 14 m tons/ha on small farms and 70-90 m tons/ha from plantations/commercial farms (Laude, 2002). Papaya grown under small scale farming has little input application, hence, yield levels are low and variable mainly due to pest and disease incidence. Yields of even the newly developed high-yielding papaya varieties have remained low due to the increasing incidence of PRSV. A large proportion (92 percent) of production is consumed domestically, but export production has been growing in the southern part of the country where PRSV is not a problem (BAS, 2006).

Papaya ring spot virus was first detected in the Philippines in 1982 in the Southern Tagalog and Bicol regions, causing substantial damage to papaya orchards (PCARRD, 2004). With an occurrence of 60-100 percent, PRSV almost wiped out the papaya industry in Southern Tagalog, a major papaya growing region in the country (Gonzales et al., 2003). The virus is widespread in Luzon, some parts of the Visayas and may spread in Mindanao where papayas are grown for export by multinational companies.

The PRSV affects all stages of plant growth from seedling to maturity. Green concentric ring spots appear on the fruit surface. Other symptoms include yellowing, mosaic and deformed leaves (PCARRD, 2004). Papaya plants infected with the virus exhibit a dramatic decline in yield. Only the *Sinta* variety developed in 1995 in the Philippines can provide moderate tolerance to the virus but it also must be combined with other disease management practices to effectively prevent and reduce the spread of the disease (Magdalita, 2000).

Papaya Biotechnology R&D in the Philippines[1]

The absence of a variety totally resistant to PRSV motivated researchers at the Institute of Plant Breeding, University of the Philippines Los Baños (IPB-UPLB), to develop PRSV-resistant papaya through genetic engineering. The Philippine government has supported the papaya genetic engineering project starting in 1998 through the Department of Science and Technology (DOST), Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (DOST-PCARRD). Additional funding support was provided by ISAAA and USAID through ABSPII.

Biotechnology research to develop a PRSV-resistant transgenic papaya involved the success in inducing somatic embryogenesis in papaya and availability of appropriate vector constructs containing the gene of interest. Transgenic papayas containing the coat protein (cp) gene of the Philippine isolate were produced through *Agrobacterium*-mediated transformation and screened against PRSV under greenhouse conditions. Three candidate transgenic lines were identified from the original 168 transformation T_0 lines. Resistant T_1 lines have already been generated, advanced and evaluated under contained and confined trial conditions.

This economic evaluation aimed to: (i) assess the potential benefits of the PRSV-resistant technology in quantitative terms, and (ii) estimate the value and distribution of the economic benefits under varying economic conditions. Small-scale papaya producers are expected to be the primary beneficiaries of this technology as the reduction in PRSV damage translates to higher productivity and income and lesser production costs.

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[1] Adapted in part from PCARRD (2004)

Methodology

This study followed the analytical framework as outlined in Chapter 2. The required data were collected from primary and secondary sources. The primary data consisted of interview surveys undertaken at three levels. The first survey involved focused group discussions (FGDs) with 56 papaya farmers in five major papaya growing provinces in the Philippines (Cavite, Laguna, Misamis Oriental, Davao del Sur and South Cotabato), which were in turn selected to represent differences in scale of operation and varietal use. Farmers participating in the FGDs were key informants chosen by the barangay head. Small scale farming operations are common in Cavite and Laguna with native and *Sinta* varieties, while larger scale operations are common in Misamis Oriental, Davao del Sur and South Cotabato, with native and *Solo* varieties for the export market. The FGDs centered on cropping practices, particularly on variety and pesticide use, farm budget information, input-output relationships, marketing, and problems in papaya production. These FGDs were supplemented by a survey of five papaya scientists and eight industry experts to elicit information on expected yield and cost changes from using the PRSV-resistant papaya technology, time and costs of product development and regulation, technology effectiveness, and unintended environmental effects. The scientists were papaya researchers from public research institutions while the industry experts were selected from papaya industry associations, regulators, and extension workers.

Results and Discussion

Survey of Papaya Farmers, Researchers and Industry Experts

Before analyzing the economic impacts of PRSV-resistant papaya variety in the Philippines, it is important to establish the baseline economic information characterizing the country's existing papaya production environment. This section presents data and information generated from the farmer FGDs and the interview surveys of scientists and industry experts.

Table 1 shows a general description of papaya farmers' characteristics obtained from the FGDs. Papaya farmers are mostly middle-aged with an average household size of five members. Average family monthly income from sources other than papaya farming was about PhP15,000. The farm sizes were on average small at 3.8 ha, with only 1.8 ha planted to papaya. Farmers, however, indicated that they plan to increase the area planted to papaya by as much as 2.1 ha.

Table 1. Selected socioeconomic characteristics of papaya farmers (averages), Philippines, 2005

Characteristics	Southern Luzon (Cavite, Laguna)	Northern Mindanao	Southern Mindanao (South Cotabato)	All
Farmers' age (years)	49.8	43.6	51.2	47.8
Household size	5.0	5.2	5.4	5.2
Monthly income (PhP)	8,611	22,492	14,500	14,729
Total farm area (ha)	3.4	2.3	7.8	3.8
Area planted to papaya (ha)	0.4	2.4	4.0	1.8
Years in farming	19.0	11.1	17.4	15.8
Years in papaya production	10.3	9.4	4.1	8.9
Proposed area for papaya expansion (ha)	1.2	2.4	3.9	2.1

Farm Level Effects of the PRSV-Resistant Biotech Papaya

Effects on Production Cost

The adoption of the PRSV-resistant variety is projected to result in changes in papaya production costs. Pesticide applications to control the virus vectors will likely decrease, but costs for inputs such as seed and harvest labor may increase. With healthy papaya plants, farmers would likely intensify production activities to attain higher yields. Table 2 shows the estimated per-hectare cost of papaya production with and without the PRSV-resistant variety technology.

Farmers commonly employ hired labor in major farming operations such as land preparation, planting, weeding, fertilizer and pesticide application, and harvesting. In papaya production without the PRSV-resistant technology, fertilizers and hired labor are the largest cost items, contributing 49 percent of total cost per hectare, which in turn is estimated at PhP64,529 with a per kilogram cost of PhP4.40[2]. Meanwhile, the cost of papaya production can reach as high as PhP303,059 per hectare in commercial/plantation-scale farms (Laude, 2002).

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[2] This cost estimate is very conservative and represents samples from all types of papaya farms as reported by BAS from a 2003 nationwide survey (BAS, 2003)

Table 2. Papaya annual production costs, without and with the use of PRSV-resistant technology (in 2003 PhP/ha)

Cost Item	Without [a]	With	% Change
Seed	105	131	25
Hired labor	21,577	28,050	30
Pesticides	6,132	4,844	- 21
Fertilizers	19,886	19,886	0
Marketing costs	796	1,018	28
Other costs [b]	16,033	16,033	0
Total cost	64,529	69,962	8
Yield (kg/ha)	14,670	25,966	77
Cost per kg	4.40	2.69	- 38

Source: BAS (2003) and author's survey

[a] Taken from BAS (2003)

[b] Include other variable and fixed costs

Scientists and industry experts said that for "with technology" farms, the costs of seeds, hired labor, pesticides, and marketing costs will likely change. Higher plant survival and greater volume of output will require more (hired) labor particularly for crop care and harvesting, thereby increasing labor costs by an estimated 30 percent. Pesticide use is expected to decrease, and the estimated reduction in pesticide cost is about 21 percent or PhP1,288 per hectare. This cost reduction does not include the environmental costs saved due to fewer pesticide applications. Production will also increase, thereby increasing the costs of other inputs leading to higher total costs. Overall, the production cost per kilogram of papaya decreased by 38 percent with the expected 77 percent increase in yield, hence resulting in a downward shift of the supply curve with technology adoption.

Effects on Yield and Income

The potential yield and income effects of the PRSV-resistant variety are analyzed by comparing the enterprise budgets in papaya farming between those with and without the proposed technology. The "without technology" case used the BAS-reported 2003 enterprise budget, while the "with technology" case used an enterprise budget constructed based on the estimated yield and cost changes reported from the FGDs and scientist and industry experts' surveys. As discussed earlier, the use of PRSV-resistant varieties will substantially reduce yield losses, but will also change the farm cost structure through increased cost of seed, reduced pesticide use, and added output. With higher cropping intensity for the "with technology" farms and better growing conditions, absolute papaya yield levels will also increase, resulting in greater benefits than costs. Table 3 shows the projected increase in yield and income when PRSV-resistant variety is adopted.

Table 3. Papaya yield and per-hectare income without and with the use of PRSV-resistant variety, Philippines, 2005

	Without [a]	With [b]	% Change
Total production cost (PhP)	64,529	69,962	8
Yield (kg/ha)	14,670	25,966	77
Output price per kg (PhP)	6.00	6.00	---
Gross returns (PhP)	86,846	153,719	
Net income (PhP)	22,317	83,757	275

[a] BAS (2003)

[b] Author's survey

The scientists' confined field trials indicated that the PRSV-resistant technology can increase yield by as much as 77 percent. Under controlled conditions, the potential yield increase was reported to be as much as 95 percent. These results clearly manifest the increase in total productivity. At the same output price, the PRSV-resistant technology also increases per-hectare net income by 275 percent.

As such, partial budget analysis shows that, although production costs increase, the additional benefits of using PRSV-resistant technology outweigh the incremental costs (Table 4). First, less pesticide application reduces production costs by PhP1,288 per hectare. Likewise, with less damage from the virus, higher yields are attained with an incremental value of PhP66,873 per hectare, and the resulting incremental benefits are PhP68,161 per hectare.

Market Level Effects of the PRSV-Resistant Biotech Papaya

The per-hectare income gains from using the PRSV-resistant technology may be significant, but they do not represent the expected benefits from the economy's viewpoint. An economic surplus analysis will quantify its benefits and provide a more comprehensive assessment of the likely effects at the national level.

Table 4. Partial budget analysis on the effects of the PRSV-resistant technology, Philippines, 2005

Incremental benefits	PhP per hectare	Incremental costs	PhP per hectare
Reduced cost		Added cost	
Pesticides	1,288	Seeds	26
		Hired labor	6,473
		Marketing costs	222
Added returns		Reduced returns	---
Increased revenue	66,873		
Total	68,161	Total	6,721
Net benefit = 61,440			
Benefit-cost ratio = 9:1			

Base Model Assumptions and Parameter Values

This section describes how key parameter estimates needed in the model for *ex-ante* analysis were obtained from primary and secondary data. The projection period covered in this study is for 15 years from 2003 to 2017.

Supply elasticity. No empirical study conducted in the Philippines provides estimates on the supply elasticity of papaya. Consultations with fruit experts revealed that the supply elasticity of mango is estimated at 0.4 - 0.6. Since there is less asset fixity in papaya production, a more elastic supply elasticity of 0.8 is assumed in this study. Relative to mango, papaya prices need to increase less to induce farmers to produce more papayas.

Research and regulatory lag refers to the period required to make the technology available in the market. Table 5 shows the indicative research and regulatory period and costs from technology research stage to commercialization; commercialization takes an estimated 12 years from when the research began.

Adoption rate. The scientists and industry experts indicated that the adoption path for the PRSV-resistant technology could follow that of *Sinta* papaya. After the commercialization of *Sinta* in 1995, its adoption rate was estimated at 30 percent in the first year and reached a maximum of 90 percent after six years, an annual 10 percent increase. In this study, determining the maximum adoption rate considered the fact that the papaya plantations in Mindanao, which cater mainly to the export market, do not necessarily favor the PRSV-resistant technology as these markets strongly discriminate against transgenic commodities. These plantations cover about 10 percent of the total area devoted to papaya in the Philippines.

Table 5. Research development and regulatory time and costs of the PRSV-resistant technology, Philippines, 2005

Activity	No. of years	Cost (PhP million)
Technology development	2	1.6
Regulatory process		
Containment	3	2.6
Limited field trial	2	3.6
Multi-location field trial	2	4.5
Food safety assessment	2	2.5
Commercialization	1	1.7

Source: Author's survey of scientists and industry experts.

Expected yield increase. The scientists interviewed in this study estimated that, based on their field trials, the PRSV-resistant technology may give 65-95 percent yield increase, with a most likely increase of 77 percent.

Change in cost per hectare. This parameter value represents the combined input cost changes that result from the adoption of the PRSV-resistant technology. It includes changes in the cost of seeds, hired labor, pesticides, and output marketing. The value of 8 percent increase in cost was used (see Table 3).

Probability of research success. The scientists interviewed estimated the probability of the technology's success at 83 percent, with a range of 80-90 percent. They reported that this estimate is reasonable considering that some tests still need to be conducted before the technology's complete success can be confirmed.

Technology depreciation. Scientists and other experts noted that, for transgenic crops already commercialized for 10 years, depreciation is yet to be observed. In this study, a conservative estimate of a linear depreciation was adopted 10 years after the PRSV-resistant technology is commercialized.

Exogenous output growth rate is the anticipated proportionate change in output not due to research in each year. This was estimated at 0.81 percent, considering only the area growth rates in Luzon and Visayas; the area growth rates in Mindanao were exceptionally high (more than 10 percent) due to the rapid expansion of *Solo* papayas for export. Since commercial plantations in Mindanao discriminate against transgenic papayas, its effect on output growth was not considered.

***Prices and discount rate*[3].** The price of papaya was assumed to be constant at 2003 levels because, although it trades papaya, the Philippines is small relative to the world export market and hence cannot influence the world price. This study used a price level of PhP19,640 per metric ton, given that there are no existing distortions in the papaya market. This study also assumed a discount rate of 5 and 10 percent to estimate the stream of benefits and costs for 15 years.

Base Model Results

The *ex-ante* economic surplus analysis revealed that the PRSV-resistant technology is likely to bring about substantial aggregate welfare benefits to papaya producers. In 2003, the value of papaya production in the Philippines amounted to PhP2.56 billion. The estimated value after commercialization of the PRSV-resistant technology was PhP2.6 billion, resulting in a change (an increase) in producer surplus of PhP650 million. Given the small open economy assumptions made, the benefit accruing to all papaya producers or the total economic surplus for the 15-year period of 2003-2017 was estimated to be PhP19.82 billion (Table 6). Even with the research cost of PhP6.4 million, the stream of net benefit amounted to PhP11.68 billion (discounted at 5 percent). These results demonstrate the importance of the PRSV-resistant technology to the growth of the papaya industry.

Table 6. Base model simulation results on the effects of the PRSV-resistant technology, Philippines

Incremental benefits	Value (PhP billion)
Total economic surplus (producers' surplus only)	19.82
Research cost	0.64
Net benefit:	
NPV at 5%	11.68
NPV at 10%	7.19

---

[3] In 2003, the official foreign exchange rate was 1 USD = PhP54.00.

Sensitivity Analysis

This section presents the sensitivity of the profitability and welfare base model results to changes in the values of some parameters (Table 7). Producer benefits increased by as much as 64 percent when supply was assumed to be less elastic than 0.8. Similarly, increasing the expected yield change to 95 percent produced a 31 percent higher welfare benefits. Needless to say, the converse was true with a lower expected yield. (An expansion in output benefits the economy through higher foreign exchange earnings.)

Table 7. Sensitivity analysis of the PRSV-resistant technology with different scenarios, Philippines

Scenario	Total economic surplus (PhP billion)	Net benefits (PhP billion)	
		NPV at 5%	NPV at 10%
Base model	19.82	11.68	7.19
Increase in input cost[a]	18.68 (- 6)	11.01 (-6)	6.77 (-6)
Change in technology adoption path[b]	22.90 (16)	13.84 (18)	8.73 (21)
Yield increase			
65% increase	15.99 (-19)	9.43 (-19)	5.80 (-19)
95% increase	25.95 (31)	15.28 (31)	9.39 (31)
Decrease in supply elasticity[c]	32.42 (64)	19.11 (64)	11.76 (64)
Five-year delay in commercialization[d]	8.04 (-59)	4.26 (-63)	2.33 (-67)
Simultaneous change in technology adoption path and yield increase[e]	30.06 (52)	18.15 (55)	11.44 (59)

Figures in parentheses are percentage changes from the base values

[a] Input cost per hectare is doubled

[b] The initial technology adoption rate is 50%, increasing by 10% until 2007, and by 90% thereafter

[c] Supply elasticity was set at 0.5

[d] Commercialization was moved to 2012

[e] Using the change in adoption path and a yield increase at 95%

Given a higher rate of PRSV-resistant technology adoption (an increase of 50 percent at the initial year), the net present value of net benefits increased by 18 percent at a discount rate of 5 percent. Assuming a higher discount rate of course reduced the value of net benefits. Compared to yield changes, the model was less sensitive to changes in costs, with increased input costs reducing benefits by only about 6 percent.

The sensitivity analysis showed that a delay in the commercialization of the PRSV-resistant technology and a reduction in supply elasticity each had very strong impacts on producers' welfare. A five-year delay in technology commercialization can reduce producers' welfare by as much as 63 percent. This indicates the urgency of having a technology that can effectively control PRSV in the country today. Papaya producers will greatly benefit if measures to mitigate the disease are made available as soon as possible. Combining the effects of higher adoption rates and a 95 percent yield improvement due to the PRSV-resistant technology resulted to a more than 50 percent increase in producers' welfare.

Summary and Conclusions

The papaya ring spot virus (PRSV) is a major disease in the Philippines that can reduce yields by as much as 80 percent in some regions. Unfortunately, all the available Philippine papaya varieties are PRSV-susceptible except for the PRSV-tolerant *Sinta* hybrid variety. To address the worsening damage attributed to the disease, a transgenic papaya variety totally resistant to PRSV was produced at IPB and is currently undergoing regulatory testing prior to commercialization. This study quantitatively assessed the potential farm-level economic benefits of the new PRSV-resistant papaya variety and evaluated the market-level distribution of those benefits under varying economic scenarios. This study was conducted in the five major papaya-growing provinces of Cavite, Laguna, Misamis Oriental, Davao del Sur, and South Cotabato. Focus group discussions (FGDs) with papaya farmers were conducted to generate the required primary information, which was in turn supplemented by interviews with scientists and industry experts. The analysis involved partial budgeting with and without the technology framework. The market effects were then estimated using economic surplus analysis, assuming a small open economy for papaya.

The adoption of PRSV-resistant technology will expectedly effect changes in papaya production costs, more specifically those relating to seed, hired labor, pesticide, and marketing. With the technology, seed and marketing costs are likely to increase, but this increase is likely to be matched by a decrease in pesticide expenditures by 21 percent. Total cost will likely increase by 8 percent, but there will likely be a 38 percent reduction in per-kilogram cost due to higher outputs. With reduced losses from PRSV, there may be a 77 percent yield advantage in using the PRSV-resistant variety, translating to a 275 percent increase in net farm income.

At the market level, the PRSV-resistant technology will result in significant welfare gains to papaya producers, with total net benefits amounting to more than PhP11.68 billion discounted at 5 percent for the period 2003-2017. The advantage of adopting the PRSV-resistant technology will depend to a large extent on market supply elasticity, time of commercialization, and expected farm-level yield increase of the PRSV-resistant variety. A decrease in the supply elasticity and a delay in commercialization by five years appear to provide the largest relative welfare loss. The most notable effects of adopting the PRSV-resistant technology were observed due to changes in supply elasticity and yield. Increasing the expected yield effect of the technology substantially increases the producers' welfare benefits. Similarly, as supply becomes more inelastic, producers respond less readily to changes in prices. The combined effects of increasing the expected yield and adoption rate produce a more than 50 percent gain on producer's welfare.

In conclusion, the PRSV-resistant technology will likely produce substantial welfare gains to papaya producers. The application of fewer pesticides is significant as well as health and environmental risks are minimized.

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Chapter 4

Costs and Benefits of *Bt* Eggplant with Resistance to Fruit and Shoot Borer in the Philippines

S.R. Francisco

Introduction

Eggplant, *Solanum melongena* L., is one of the most economically important vegetable crops in the Philippines currently valued at PhP3.44 billion (BAS, 2008). Production generally increased from 1990 to 2007, same with area except in 1998 (Figure 1). Yield followed a pattern similar to production until 1999 when it barely moved. Nevertheless, eggplant accounted for an average of 29 percent of the total quantity of vegetables produced, equivalent to an average of 185,153 metric tons from 2000-2007 (BAS, 2008).

As with other vegetables, eggplant prices are highly seasonal in the Philippines – low during the summer months of March to May and high during the colder months of November to January. This price pattern reflects the volume of product available in the market. At constant prices, the value of eggplant production remained to be the highest among vegetables in the Philippines from 2000-2007. Within the same period, the top eggplant producing provinces were Pangasinan, Quezon, and Isabela which gave an average combined production of 93,095 metric tons. Pangasinan and Quezon accounted for nearly 50 percent of total eggplant production in the Philippines.

Recently however, eggplant production in the Philippines has been seriously affected by a host of problems, the most damaging of which is the eggplant fruit and shoot borer (EFSB) (*Leucinodes orbonalis* Guenee). Farmers have reported finding it difficult and expensive to control, hence affecting yields

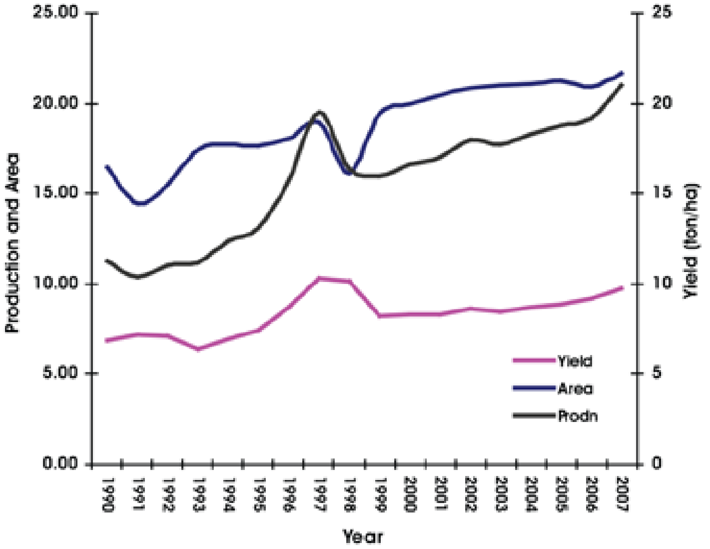


Figure 1. Eggplant area harvested, production and yield, Philippines, 1990-2007 (Source of basic data: BAS, 2008.)

and making production risky and costly. With increased costs of production brought about by high expenditures for fertilizers, pesticides and labor, the profitability of eggplant production has been declining since 1997 (Table 1 and Figure 2). Although income increased from 2004, there is a wide variability in profit.

Research to Address EFSB

The realization that conventional pesticides can cause problems has stimulated the search for alternative strategies to control EFSB. One project undertaken to control EFSB has been the Integrated Pest Management–Collaborative Research Support Program (IPM-CRSP). The project has researched various combinations of techniques such as cultural control, host plant resistance, and judicious chemical control to reduce pest infestations to economically acceptable levels. However, only a few recommended practices have been widely adopted.

Another project, the Agricultural Biotechnology Support Program II (ABSPII), has sought to develop and commercialize transgenic EFSB-resistant (or *Bt*) eggplant for resource-limited farmers in India, Bangladesh and the Philippines through public-private sector partnerships. ABSPII is collaborating with India-based Maharashtra Hybrid Seeds Company (Mahyco), which has developed a *Bt* eggplant donor event, EE-1. The transformation involved genetic modification using *Bt* technology to confer resistance against the targeted insects. A gene encoding insecticidal protein cry1Ac from *Bacillus thuringiensis* (*Bt*) have been introduced into Mahyco eggplant line to develop resistance against EFSB. Transgenic Mahyco *Bt* eggplant hybrids derived from Mahyco event EE-1 have completed several multi-location and large scale field trials in India (Choudhary and Gaur, 2008). This chapter summarizes an *ex-ante* assessment of the economic impact of this transgenic crop if it were to be introduced as a component of an Integrated Pest Management (IPM) program in the Philippines.

Table 1. Costs and returns (PhP/ha) of eggplant production, Philippines, 1998-2003

Item	Year					
	1998	1999	2000	2001	2002	2003
Costs (PhP)						
Seeds	1,032	1,271	1,311	1,507	1,335	1,344
Fertilizer	8,254	6,944	7,470	8,893	8,775	10,963
Pesticides	14,164	12,708	13,670	16,274	16,058	20,063
Labor	22,733	27,313	27,572	27,583	28,483	30,158
Other costs*	18,664	19,992	20,928	23,177	22,607	24,218
Total production cost (PhP)	64,847	68,228	70,951	77,434	77,258	86,746
Yield (kg)	10,182	8,244	8,329	8,315	8,630	8,430
Price per kg	8.33	10.26	10.58	12.16	10.77	10.84
Gross revenue (PhP)	84,816	84,583	88,121	101,110	92,945	91,381
Net income (PhP)	19,969	16,356	17,169	23,677	15,687	4,635

Source: BAS (2004)

* Other costs include rents, fuel & oil, transport, irrigation fees, interest on capital, landlord shares

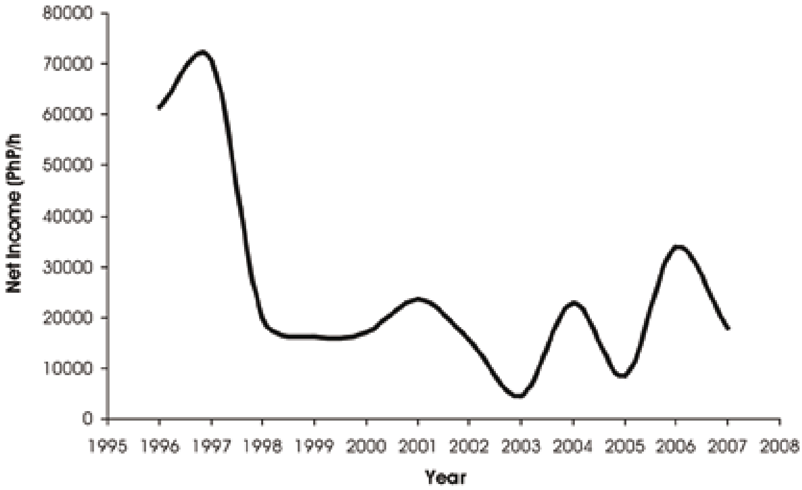


Figure 2. Profitability of eggplant production, 1996-2007 (Source of basic data: BAS, 2008)

Objectives

Any program that attempts to introduce a new technology is often confronted with questions such as: How profitable is the technology? What are its impacts or benefits? What is its return on investment? Answers to these questions are needed by farmers (technology users) who desire information on field level results, by funding agencies who are interested in macro-level impacts, and by policy makers to have basis for wider scale of program implementation. To help answer these questions, this study aims to undertake an *ex-ante* economic impact assessment of developing and commercializing *Bt* eggplant in the Philippines. More specifically, this assessment was undertaken to:

1. examine the impacts of *Bt* eggplant adoption on farm income, costs, and pesticide and labor usage, and
2. project the size and distribution of economic benefits to society from developing and commercializing *Bt* eggplant.

The results of this study can serve as a basis for recommending to farmers an effective strategy to manage fruit and shoot borer in eggplant as well as for evaluating the market level benefits of the technology.

Methodology

Data and Sources

Following the general analytical framework discussed in Chapter 2, this study collected primary data from focus group discussions (FGDs) with a total of 77 farmers in five FGDs , interviews of four eggplant scientists and two industry experts, including seed company representatives, 10 extension workers, and two product regulators. Secondary data were gathered mainly from the Philippine Department of Agriculture Bureau of Agricultural Statistics (DA-BAS) and the Philippine Rice Research Institute (PhilRice).

The FGDs were conducted in the five eggplant producing provinces of Batangas, Nueva Ecija, Nueva Vizcaya, Pangasinan and Quezon. The municipalities covered include, Tanauan in Batangas, Talavera in Nueva Ecija, Aritao in Nueva Viscaya, Asingan in Pangasinan, and Candelaria in Quezon. Farmers from these FGDs came from different barangays of the identified towns. In 2003, Pangasinan and Quezon together produced about 85,300 mt of eggplant, or more than 50 percent of total production in the Philippines. In the same year, Pangasinan and Nueva Ecija accounted for almost 30 percent of total area planted.

The farmer FGDs elicited information on yield losses caused by EFSB, variety use and sources, pest management practices, input costs, and means of product disposal, among others. Information obtained from the scientists, included expected yield gains from solving the problem of EFSB, changes in input costs associated with controlling EFSB and with use of *Bt* eggplant, the probability of success in developing *Bt* eggplant, R&D and regulatory costs of developing and commercializing *Bt* eggplant, and the variety to incorporate the *Bt* and the unintended effects of *Bt* eggplant. The industry experts interviewed included seed industry players, extension agents, and government regulators. Information obtained from these industry experts included annual crop loss due to EFSB damage, preferred varieties, source of seeds, technology development and regulatory lags, maximum adoption rate (area planted) once *Bt* eggplant is released, years before reaching the maximum adoption rate, and the cost of research and meeting regulatory requirements before *Bt* eggplant is released.

Meanwhile, secondary data collected from the Bureau of Agricultural Statistics (BAS) included eggplant production, area, yield, prices, and production costs and returns, both at the national and at the provincial levels. Experimental data on yields were also gathered from PhilRice and its IPM-CRSP studies.

Data Analysis

To assess the potential impacts of *Bt* eggplant adoption, a partial budget was constructed to reflect changes in seed use, pesticide and application labor, yield changes, and farmers' income using the data and information gathered from the different stakeholder interviews and secondary data on eggplant cost and return. The economic surplus model was then applied to evaluate and quantify the potential benefits and costs of *Bt* eggplant technology to producers and consumers, and to project the size of aggregate impacts and their corresponding distribution. A closed economy model for the eggplant market was assumed because few eggplants are traded internationally.

The eggplant supply and demand functions were assumed to be linear. The model was run for a 15-year time horizon starting from 2008, after which the technology is assumed obsolete. A high adoption rate was assumed for the *Bt* eggplant technology because it is not a significant departure from existing farmer practice, and its profitability would be substantial.

Although eggplant is an important crop in the Philippines, information on its elasticities of supply and demand are very limited. Orogo (1976) estimated the elasticities of selected vegetables, except eggplant; the estimated demand elasticity of fruit vegetables was at -0.75 and of all vegetables at -0.85. This study assumed the demand elasticity of eggplant to be within this range (at -0.8) considering that eggplant is a fruit vegetable. A supply elasticity of 0.5 was assumed considering the nature and high seasonality of eggplant production. Sensitivity analysis was conducted by varying the assumptions used in the analysis.

Results and Discussions

Survey of Eggplant Farmers, Researchers and Industry Experts

Tables 2 and 3 present the summary findings across the five FGD provinces. Eggplant farmers reported that yield losses due to EFSB ranged from 28 to 64 percent (Table 2). In some cases, farmers reported yield losses of 90 percent. Majority of the farmers interviewed planted hybrid eggplant seeds (Casino, Jackpot and Domino varieties), although some farmers reported that they use home-saved seeds for home consumption. The East-West Seed Company, the leader in vegetable seed sales in Luzon, is the major source of hybrid seeds. Farmers reported using 50 to 100 grams per hectare and spending PhP400 to PhP1,400 per hectare for the hybrid seeds. In marketing, farmers dispose of their output either by direct marketing, selling to traders/local assemblers, or by bringing them to a nearby trading post or to Metro Manila where major consumption takes place.

Table 2. Summary of information processed from eggplant farmer FGDs, Philippines, 2005

Item	Response
Yield loss	28-64%
Variety used	Casino, Jackpot, Domino, home-saved seeds
Seed sources	Agricultural supplier, East-West Seed Company, co-farmers
Seed usage	50-100 grams per ha
Seed cost	PhP 400-1,400 per ha
Market outlets	Direct marketing, traders, trading posts, Metro Manila

Table 3. Input usage and cost per ha from farmer FGDs, Philippines, 2005

Statistics	Insecticides		Application labor (PhP/ha)	Frequency of spraying (No./ha)	Fertilizer cost (PhP/ha)	Seeds	
	Qty (li/ha)	Cost (PhP/ ha)				Qty (gm/ ha)	Cost (PhP/ ha)
Min	5	1,250	2,000	10	2,480	50	400
Max	115	57,500	16,000	80	26,400	100	1,400
Average	31	14,581	7,398	37	10,512	77	963
Mode	20	16,000	8,000	40	10,000	100	1,200

The eggplant farmers interviewed sprayed a minimum of 5 li and a maximum of 115 li for the 5-6 month duration of eggplant production (Table 3). The mean volume of insecticides used was 31 li/ha, although most farmers applied only 20 li/ha. On average, eggplant farmers spent PhP10,512/ha on fertilizers, PhP14,581/ha on insecticides and PhP7,398/ha for pesticide application hired labor. The IPM CRSP baseline surveys in 1994 and 1999 found that eggplant farmers in Nueva Ecija sprayed twice per week on average. Except for removal of damaged fruits and shoots, no other method has been reported to be effective against EFSB (Alpuerto, 1994). This control method, however, is rarely adopted by farmers because it is labor intensive and labor is limited. As such, farmers mainly rely on insecticides.

Most farmers are willing to adopt *Bt* eggplant even if its seed is more expensive than the current varieties. According to them, EFSB had caused the profitability of eggplant production to decline substantially; in many instances, the farmers reported barely breaking even because the marketable yield had been reduced to less than half the total yield – much lower than the marketable yields obtained five years earlier. The declining profit and marketability prompted the farmers to change to other crops such as yellow corn and green corn. Even if corn production did not give them high profits, the farmers felt that the risk of loss was much smaller than with eggplant.

Meanwhile, scientists perceive that farmers' adoption of *Bt* eggplant would increase eggplant yield anywhere from 23 percent to 60 percent, though most likely by 47 percent (Table 4). These estimates were larger than those given by the farmers during the FGDs. In terms of changes in variable input costs, the scientists felt that hired labor cost for pesticide application would decrease by 10 to 25 percent, pesticide cost would be reduced by about 47 percent, but increase seed cost by 50 percent. Scientists felt that there is a 73 percent probability of success in developing and commercializing *Bt* eggplant.

Table 4. Summary of eggplant scientist interviews, Philippines, 2005

	Response		Response
Yield change (%)		Lags (years)	
Min	23	Technology development	5
Max	60	Contained trial	2
Most likely	47	Limited field trial	2
Cost change (%)		Multi-location field trial	2
Hired labor	(10 - 25)	Food safety assessment	1
Fertilizer	-	Apply for commercialization	1
Pesticides	(42 - 53)	Cost involved (USD'000)	150 - 250
Seeds	50 - 100		
Probability of success (%)	73	Externality	
		Gene flow	N
		Biodiversity	N
		Non-target organism	N

The development and commercialization of a biotech crop involves several steps. The first is technology development that begins in laboratories or greenhouses, where scientists make transformations and conduct contained trials. Once the laboratory and greenhouse results are successful, the plant may advance to confined field trials, where breeding and testing continue. The third step is securing regulatory approval for multi-location field trial to generate information on crop performance in different environments where the plant will be grown and/or consumed, followed by the fourth and final step of approval for propagation, market acceptance and widespread dissemination. Scientists felt that all these steps would take about nine years to complete for a rough total cost figure ranging at USD150-250,000. They were unanimous in saying that there would be no serious unintended effects associated with *Bt* eggplant, basing their views on the experience with *Bt* corn in the Philippines and with other *Bt* crops being cultivated in other countries such as the United States.

Meanwhile, seed industry representatives and extension agents opined that the yield loss due to EFSB can range from 35 percent to 50 percent, a range narrower than the farmer estimates (Table 5). The most popular varieties are Casino and Jackpot, which are produced and distributed by the East-West Seed Company. They also gave a probability of 70 to 90 percent chances of success in developing and commercializing *Bt* eggplant.

Table 5. Summary of industry expert interviews, Philippines, 2005

	Response
Yield loss (%)	35 - 50
Varieties	Casino, Jackpot
Sources	East-West Seed Co, agricultural suppliers
Probability of success (%)	70 - 90
Lags (yrs)	
Development	4
Contained trial	1
Limited field trial	2
Multi-location field trial	2
Food safety assessment	3
Application for commercialization	1
Cost involved (USD'000)	120 – 200 (from R&D to commercialization)
Maximum crop area planted	40 - 60% in 3 - 5 years
Change in area	5 - 10% decline per year if trends in EFSB infestation continue

Industry experts forecasted the time lag required to develop and commercialize *Bt* eggplant at about 10 years with a total expenditure of USD120-200,000 and a maximum adoption of 40 to 60 percent. If no effective solution will be available to manage or control EFSB, there would be a decline of 5 to 10 percent per annum in area planted to eggplant.

Potential Farm-Level Effects of *Bt* Eggplant

Potential technology effects on the cost and income of eggplant production at the farm level were estimated based on FGDs results and interviews with scientists and industry experts. The estimation included only variable costs because it assumed that fixed costs (e.g., land/land rental, machinery, tools, irrigation) would be the same with and without *Bt* eggplant variety. Table 6 summarizes the results of this estimation.

Table 6. Estimated changes in *Bt* eggplant farm budget based on farmer FGDs and experts' interviews, Philippines, 2005

	Response
Variable cost	
Seed	50 - 100% increase
Fertilizer	No change
Pesticides	50 - 60% decrease
Labor	10 - 25% decrease
Pesticide labor	Pesticide application to decrease by 60%
Other labor	No change
Other	No change
Yield and returns	
Yield (kg/ha)	28 - 64% increase
Price per kg	No change
Gross return	28 - 64% increase

Seed Cost

Determining how much seed companies will charge for *Bt* eggplant varieties is difficult for several reasons. First, while seed company representatives said that they would charge a price higher than the price of their current premium variety, they could not estimate the new price until they saw the performance of the finished variety. In addition, the price they would charge would depend upon whether or not other companies are able to develop and release varieties with similar traits. The interviews with scientists, however, indicated that farmers who adopt a *Bt* eggplant variety would likely face a 50-100 percent increase in seed costs.

Pesticide Cost

Based on the FGDs and interviews with experts, *Bt* eggplant could reduce farmers' spraying for EFSB by 50 to 60 percent, thereby reducing expenditures on insecticides by that amount.

Labor Cost

Scientists and industry experts estimated that, if *Bt* eggplant were planted, labor cost in eggplant production would be reduced by 10 to 25 percent, which in turn would come from reduced pesticide applications. Farmers felt that they would cut down their application by at least 60 percent with *Bt* eggplant.

Yields and Returns

Farmers and industry experts indicated yield losses of 28 to 64 percent to EFSB. Assuming that EFSB could be fully controlled by planting *Bt* eggplant, this would mean that marketable yield would increase by that same amount, resulting in an equal increase in gross revenue (assuming no product price increase).

Other Costs

Marketable yields were expected to increase with the use of *Bt* eggplant. However, harvesting and post harvest labor costs would not be expected to change since labors would be handling the same volume of output (they just would not have to sort out the damaged fruits).

Income and Cost Effects of *Bt* Eggplant

Enterprise and partial budgets for 2002 and 2003 eggplant production were constructed, with and without the new technology (Table 7). In both years, seed cost comprised only a small portion (less than 2 percent) of total production cost. This analysis shows that the adoption of *Bt* eggplant would decrease production costs due to a reduction in pesticide and pesticide application labor. The use of pesticides would potentially decrease by 55 percent while pesticide labor cost would decline by 60 percent. With the prevented yield loss, marketable output would increase by 40 percent. The use of *Bt* eggplant hence would increase net income substantially.

Table 7. Partial budgets projected for *Bt* eggplant production compared to actual 2002 and 2003 crop budgets (PhP/ha)

	Crop budgets			Crop budgets	
	2002	**2003**		**2002**	**2003**
Incremental benefits			Incremental costs		
Reduced costs			Added costs		
Pesticide cost	8,832	11,035	Seed cost	1,335	1,344
Hired labor	5,127	5,428			
Added returns			Reduced returns	–	–
Increased revenue	37,178	45,691			
Total incremental benefits	51,137	62,154	Total incremental costs	1,335	1,344
Net incremental benefits	49,802	60,810			

USD1.00 = PhP55.00
Source of basic data: BAS (2004)

Using the 2002 crop budget from BAS, the adoption of *Bt* eggplant would reduce the cost of using insecticides by a total of PhP13,959 per ha. This decreased cost was brought about by the reduction in pesticide applications and concomitant labor costs. The adoption of *Bt* eggplant would prevent damage to the crop from EFSB and hence increase marketable yield and revenue. Farmers, however, would incur an increased cost of seed of PhP1,335 per ha, assuming that *Bt* eggplant seed are more expensive. The resultant increase in profits for *Bt* eggplant would be PhP49,802 per ha.

Welfare Effects

Changes in economic surplus were computed based on technical coefficients derived from the partial budgets, assumed adoption rates, and elasticities of demand and supply (Appendix 1 presents the basic spreadsheet used in this study). The expected yield difference between *Bt* eggplant and current non-transgenic eggplant varieties was 40 percent, and the expected net cost reduction due to *Bt* eggplant variety was 16 percent. A discount rate of 5 percent was used in the model. Table 8 summarizes the projected net benefits and their distribution.

Table 8. Projected changes in economic surpluses, research costs, net benefits and the net present value of benefits minus costs with adoption of *Bt* eggplant

	Value in PhP million
Change in consumer surplus	1,279 (38)
Change in producer surplus	2,047 (62)
Change in total surplus	3,326 (100)
Research costs	29
Net benefits	3,297
Net present value (NPV)	1,864
Internal rate of return (%, IRR)	86.85

USD1.00 = PhP55.00
Values in parentheses are percentages

The net present value of adopting the *Bt* eggplant technology was estimated at PhP1,864 million, with an internal rate of return (IRR) of 86.8 percent for the PhP29 million investment in developing and commercializing the technology. Consumers would also be safer because of reduced insecticide residues on the product. Total surplus would increase by about PhP3,326 million of which PhP1,279 million (38 percent) would go to consumers and PhP2,047 million (62 percent) would go to producers.

Sensitivity Analysis

Several parameters in the analysis can be considered as carrying some uncertainty. Expected changes in input costs, yields, supply/demand elasticities and adoption patterns were varied to determine how the benefits and their distribution would be affected. When the supply elasticity was reduced by 50 percent (supply was made more inelastic), the NPV of the benefits increased to PhP3,536 million, almost double the benefits in the base case scenario (Table 9). The change in producers' surplus more than doubled while the change in consumers' surplus increased slightly. Meanwhile, an increase of 50 percent in the supply elasticity (supply was made more elastic) reduced the NPV to PhP1,308 million. Relative to the base scenario, changes in economic surplus and NPV due to changes in demand elasticity were small compared to those for changes in the supply elasticity. However, changes in the magnitude of the demand elasticity had a large effect on the distribution of benefits between consumers and producers, with consumers benefiting from a reduction in the supply elasticity.

Table 9. Changes in NPV and economic surplus (in PhP million) under varying elasticities of supply and demand

Scenario	Change in Consumer surplus	Change in Producer surplus	Change in Total surplus	NPV	IRR (%)
Base case	1,279.09	2,046.54	3,325.62	1,864.42	86.85
	(0.38)	(0.62)	(1.00)		
Change in supply elasticity					
50% decrease in base case	1,492.78	4,776.90	6,269.69	3,536.44	105.45
	(0.24)	(0.76)	(1.00)		
50% increase in base case	1,135.60	1,211.31	2,346.91	1,308.56	77.65
	(0.48)	(0.52)	(1.00)		
Change in demand elasticity					
50% decrease in base case	1,830.08	1,464.06	3,294.15	1,846.71	86.68
	(0.56)	(0.44)	(1.00)		
50% increase in base case	983.03	2,359.26	3,342.29	1,873.79	86.94
	(0.29)	(0.71)	(1.00)		

USD1.00 = PhP55.00
Values in parentheses are shares of the total surplus change

Table 10 summarizes the effects of changes in yield and cost on changes in economic surplus, NPV and IRR for *Bt* eggplant production. A 50 percent increase in expected yield change caused increased total economic surplus by 44 percent, NPV by 45 percent, and IRR by 10 percent. Conversely, a 50 percent reduction in expected yield change reduced total economic surplus, NPV and IRR by 42, 43 and 14 percent, respectively. A 50 percent increase in input costs caused a 6 percent decrease in total economic surplus and an almost equal percent change in NPV.

Varying the Adoption Pattern

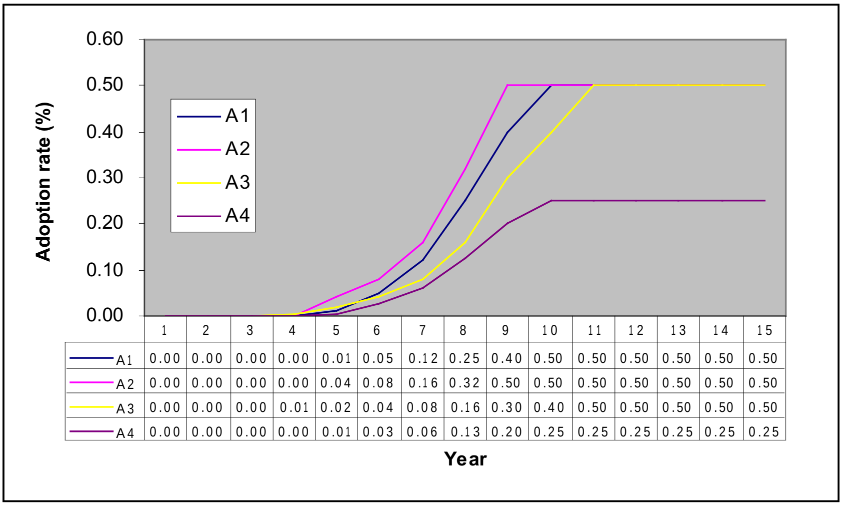
Another parameter that is critical to benefits of a technological change is the pattern of adoption by farmers. Adoption often follows an S-shaped pattern approaching its maximum level asymptotically (Alston et al., 1995). In this study, four distinct S-shaped adoption rate patterns were assumed. The base case scenario A1 had a four-year lag period and a maximum adoption rate of

50 percent; A2 had a four-year lag period, but a rate of adoption higher than A1; A3 had early adoption (only a three-year lag) but with a slower adoption rate than in A1; and A4 had the same pattern as A1 but with only half the adoption rate. Figure 3 shows these different adoption patterns and Table 11 presents the results of the sensitivity analysis.

Table 10. Changes in NPV and economic surplus with changes in expected yield and production cost

Scenario	Change in total surplus		Change in NPV		IRR (%)
	Value (PhP million)	%	Value (PhP million)	%	
Base case	3,326	-	1,864	-	86.85
Change in expected yield change					
50% increase	4,797	44.23	2,700	44.79	97.15
50% decrease	1,912	-42.49	1,062	-43.05	72.59
Change in expected cost					
50% increase	3,111	-6.45	1,743	- 6.53	85.05
50% decrease	3,541	6.48	1,987	6.56	88.57

USD1.00 = PhP55.00



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A1	0.00	0.00	0.00	0.00	0.01	0.05	0.12	0.25	0.40	0.50	0.50	0.50	0.50	0.50	0.50
A2	0.00	0.00	0.00	0.00	0.04	0.08	0.16	0.32	0.50	0.50	0.50	0.50	0.50	0.50	0.50
A3	0.00	0.00	0.00	0.01	0.02	0.04	0.08	0.16	0.30	0.40	0.50	0.50	0.50	0.50	0.50
A4	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.13	0.20	0.25	0.25	0.25	0.25	0.25	0.25

Figure 3. Adoption patterns assumed in the computation of economic surplus.

Table 11. Changes in economic surplus (PhP million), NPV (PhP million), and IRR under different adoption patterns

Parameters	Technology adoption scenarios			
	A1 (base case)	A2	A3	A4
Change in consumer surplus	1,279	1,369	1,228	629
Change in producer surplus	2,047	2,190	1,966	1,006
Change in total surplus	3,326	3,559 0.07	3,194 -0.04	1,634 -0.75
Net benefits	3,297	3,530	3,165	1,605
Net present value (NPV)	1,864	2,027 0.09	1,711 -0.08	904 -0.52
IRR (%)	86.85	103.46 0.19	89.26 0.03	68.81 -0.37

USD1.00 = PhP55.00
Figures in italics are the percent changes compared to the base case scenario, A1
Total research cost is PhP29 million

Relative to the base case scenario, the NPV under A2 increased by more than 10 percent, and IRR increased by about 20 percent. The total economic surplus increased by more than PhP200 million (7 percent). A comparison of the base case scenario and A3 meanwhile reveals that even if the adoption rate is low, the economic surplus and NPV would not decrease dramatically as long as adoption is early. This is evidenced by only 4 percent reduction in total economic surplus and 8 percent reduction in NPV. Under adoption rate A4, economic surplus, NPV and IRR were all smaller compared to those under the base case scenario, respectively declining by 75, 52 and 37 percent.

Simultaneous Changes in Yield and Adoption

Table 12 illustrates the effects of assuming simultaneous changes in yield, cost, and adoption, while elasticities are assumed to be the same as those of the base case scenario. The results show that even if the yield gain, cost reduction, and adoption rate were at only 50 percent of the baseline assumptions, investment in the development of *Bt* eggplant technology would still be profitable.

Table 12. Effects of simultaneous changes in model parameters on economic surplus (PhP million), NPV (PhP million) and IRR

Scenario	Change in Consumer surplus	Change in Producer surplus	Change in Total surplus	Net Benefit	NPV	IRR (%)
Base case	1,279	2,047	3,326	3,297	1,092	86.85
50% base case	243.61	584.66	828.27	799.27	446.05	53.65

USD1.00 = PhP55.00

Environmental Effects

While Chapter 10 presents a more detailed analysis of the environmental benefits and risks of *Bt* eggplant technology adoption, a few conclusions from the stakeholder interviews and from estimated changes in pesticide use were opted to be presented here. The FGDs found that farmers were spraying as many as 80 times per season to control EFSB. The adoption of *Bt* eggplant, therefore, would greatly reduce, if not eliminate, these pesticide applications because of the built-in insecticidal protein. This would in turn mean reduced pesticide loading in the environment that can pollute the waterways and groundwater, and cause harm to non-target organisms and species biodiversity.

Some concerns raised against genetically modified crops include unknown potential effects on gene flow, non-target species, and biodiversity. Gene flow is an ecological concern wherein genetically engineered pollen or seed might escape, spread throughout the community, and establish itself where it falls, thus becoming weeds of agriculture or invasive to the natural environment. Similarly, plants engineered to produce proteins with insecticidal properties are feared to also possibly affect the populations of non-target species. A concern is expressed that the insecticidal protein expressed in *Bt* eggplant, by secretion or upon cell death, might be toxic to the broad range of non-target organisms such as the beneficial natural predators/parasitoids, those present in soil and water ecosystems, and the fauna that may consume the transgenic crop parts. Loss in eggplant species biodiversity might occur if *Bt* eggplant could withstand the EFSB and hence, in the long run, be the only variety that could survive. These concerns, however, were unanimously rejected by the scientists interviewed for *Bt* eggplant.

Summary and Conclusion

Eggplant, *Solanum melongena*, L. is one of the most economically important vegetable crops in the Philippines. Eggplant yields and profitability, however, have been seriously threatened and affected by fruit and shoot borer (EFSB), making production risky and costly.

This study projected that the adoption of *Bt* eggplant would increase marketable yield, reduce insecticide use, and increase farmers' income in the Philippines. Using both primary and secondary data, the study also projected the size and distribution of benefits to producers, consumers, and society as a whole. Focus group discussions with farmers elicited information on yield losses and variable costs. Interviews with scientists and industry experts elicited information on time lags, probability of development and commercialization success, technology adoption and depreciation, seed pricing, and market adoption rates. Prices, area, production, and cost and return data were obtained from BAS and PhilRice-IPM CRSP project.

Farm level partial budgets were constructed to assess the incremental benefits and costs of adopting *Bt* eggplant. The size and distribution of benefits were projected using economic surplus analysis, and sensitivity analyses determined the effects of varying key assumptions.

Results indicated that at the farm level, *Bt* eggplant adoption has high potential to increase marketable yield, reduce costs, and increase profits. Partial budgeting showed that, compared to current varieties, *Bt* eggplant could provide incremental benefits of around PhP50,000 per ha. In general, the adoption of *Bt* eggplant would be economically superior to current technologies from a consumer and producer standpoint, as well as for society as a whole. However, the larger share of the change in economic surplus would go to producers as a result of the research-induced shift in the supply curve given the base elasticity assumptions (-0.8 and 0.5). Sensitivity analyses showed that the effect of supply elasticity on total economic surplus is greater than that of demand elasticity, but the latter has a greater effect on the distribution of benefits. Even if yield gain, cost reduction, and adoption pattern were only half of the baseline assumptions, investment in the development of *Bt* eggplant technology would still be profitable.

The adoption of *Bt* eggplant is projected to greatly reduce, if not eliminate, pesticide use on eggplant thereby reducing both pesticide loading in the environment and hazards to farm labor and consumers.

Since it has few (if any) unintended environmental effects, adopting the technology is a win-win situation. It may improve input use efficiency and help address poverty issues and food security concerns. Once commercialized, farmers would gain profits because the technology would increase the marketable yield and lower production costs; consumers would have an adequate supply of low-insecticide residue eggplant at a lower price; money used to buy insecticides, which have not been effective in the control of EFSB, could be used to purchase other yield-enhancing inputs. Even if yield gain, cost reduction and technology adoption rate were only half of the baseline assumptions, investment in the development of *Bt* eggplant technology would still be highly profitable.

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Appendix 1. Economic surplus spreadsheet models and base case assumptions

Year T	Elasticity of supply e	Elasticity of demand n	Expected yield change E(dY)	Change in input cost per ha E(C)	Probability of success	Rate of adoption	Depreciation rate of adoption	Price P	Quantity (base qty) Qo	Change in total econ surplus dTS	Research Cost	Net present value (NPV	Internal rate of return (IRR)
2004	0.50	0.80	0.40	-0.16	0.70	0.00	1.00	10,000	182,750	-	5,000,000	1,091,965,741	86.9%
2005	0.50	0.80	0.40	-0.16	0.70	0.00	1.00	10,000	182,750	-	5,000,000		
2006	0.50	0.80	0.40	-0.16	0.70	0.00	1.00	10,000	182,750	-	5,000,000		
2007	0.50	0.80	0.40	-0.16	0.70	0.00	1.00	10,000	182,750	-	5,000,000		
2008	0.50	0.80	0.40	-0.16	0.70	0.01	1.00	10,000	182,750	11,707,516	4,000,000		
2009	0.50	0.80	0.40	-0.16	0.70	0.05	1.00	10,000	182,750	11,707,516	3,000,000		
2010	0.50	0.80	0.40	-0.16	0.70	0.12	1.00	10,000	182,750	58,767,902	2,000,000		
2011	0.50	0.80	0.40	-0.16	0.70	0.25	1.00	10,000	182,750	134,831,027	-		
2012	0.50	0.80	0.40	-0.16	0.70	0.40	0.95	10,000	182,750	284,275,778	-		
2013	0.50	0.80	0.40	-0.16	0.70	0.50	0.90	10,000	182,750	549,640,025	-		
2014	0.50	0.80	0.40	-0.16	0.70	0.50	0.85	10,000	182,750	517,880,886	-		
2015	0.50	0.80	0.40	-0.16	0.70	0.50	0.80	10,000	182,750	486,265,698	-		
2016	0.50	0.80	0.40	-0.16	0.70	0.50	0.75	10,000	182,750	454,794,462	-		
2017	0.50	0.80	0.40	-0.16	0.70	0.50	0.70	10,000	182,750	423,467,175	-		
2018	0.50	0.80	0.40	-0.16	0.70	0.50	0.65	10,000	182,750	392,283,840	-		

Base case assumptions

Research lag : 4 yrs
A_{max} : 50%
Period d to reach A_{max} : 5 yrs from start of adoption
E(dY) : 40%
E(C) : -16%
Adoption pattern : 0, 0, 0, 0, 0,.01, 0.05, 0.12, 0.25, 0.40, 0.50, 0.50, 0.50, 0.50, 0.50
Supply elasticity, e : -0.8
Demand elasticity, n : 0.5
Discount rate : 5 and 10%

Chapter 5

Costs and Benefits of Multiple Virus Resistant Tomato in the Philippines

C.B.C. Mamaril

Introduction

Tomato (*Lycopersicon esculentum*) is widely produced and consumed in the Philippines. In 2004, the country produced an estimated total volume of 172,344 metric tons (mt), or one-tenth of all vegetable production and 10 percent more than the 1995 level. In the same year, the total area planted to tomato was 17,687 hectares and the national average tomato yield was about 10 t/ha, which was 12 percent more and 1.2 percent less than the 1995 levels, respectively. The top two tomato producing regions in the Philippines are Region I (Ilocos Region) and Region X (Northern Mindanao), while the top two producing provinces are Bukidnon and Pangasinan.

Production Constraints

Like most solanaceous crops, tomatoes are prone to several insects and diseases. Some of its more common perennial pests include ants, army worms, nematodes, bacterial wilt, and viruses. Over the past few years, a collaborative effort among Agricultural Biotechnology Support Project II (ABSPII), the World Vegetable Center (AVRDC), the International Service for the Acquisition of Agri-biotech Applications (ISAAA), and the Institute for Plant Breeding at the University of the Philippines Los Baños (IPB-UPLB) has been ongoing to address two viral constraints: tomato yellow leaf curl virus (TYLCV) and cucumber mosaic virus (CMV). Plant infections from these two viruses were limited in the past, but there is mounting evidence from extension agents, scientists, and seed company representatives who reported that a rapidly growing proportion of tomato production is being infected by TYLCV in farmers' fields. Yield losses of up to 100 percent from TYLCV infection are being reported. As for CMV, there are currently no conventionally-developed sources of resistance available. Thus, a transgenic approach was adopted by ABSPII and its collaborators to address the virus constraint.

Current Research Status

By 2004, the World Vegetable Center had developed eight parental lines considered to be possible sources of natural resistance to Philippine strains of TYLCV. The first batch of seeds was acquired by IPB-UPLB on January 2005, and a second batch in May 2005. These parental lines were subjected to multi-location testing to determine their efficacy of resistance against local TYLCV strains. Two out of the eight lines were used for introgression into three local varieties. As for hybrid multiple virus resistant (MVR) tomato, the initial F1 crosses were done at the World Vegetable Center, and the first batch of seeds was acquired in April 2005. These were also subjected to multi-location efficacy trials.

The trials were conducted in four sites, namely: (1) IPB-UPLB, (2) San Ildefonso, Bulacan, (3) Bayombong, Nueva Vizcaya, and (4) Manolo Fortich, Bukidnon. Preliminary results indicated that at least one among the nine TYLCV-resistant parental lines shows promise in terms of being resistant to Philippine strains of TYLCV. Additional trials are assessing fruit quality and other horticultural traits of promising MVR tomato lines.

The efficacy testing of the World Vegetable Center developed transgenic CMV-resistant tomato to local CMV strains has not yet been conducted. Scientists are awaiting approval from the National Committee on Biosafety of the Philippines (NCBP) to import transgenic CMV-resistant tomato material into the Philippines.

Objective and Methodology

This study aimed to evaluate *ex-ante* the welfare impact of adopting MVR tomato in the Philippines. A simple partial equilibrium closed economy economic surplus model was used to evaluate the magnitude and distribution of economic benefits from adopting MVR tomato in the Philippines. MVR tomato R&D in the Philippines is at an early stage. As such, there is uncertainty in many of the variables that will affect the outcome of successfully releasing an MVR tomato variety. As cited in Hareau et al. (2003), *ex-ante* agricultural technology evaluations often utilize deterministic values for uncertain variables, followed by sensitivity analysis to determine the robustness of results to changes in key parameter values. This study employed stochastic simulation methods to estimate the potential impact of adopting an MVR tomato variety in the Philippines. Probability distributions were assigned to expected yield increases, changes in marginal costs, price elasticities, area, production and consumption levels, and the probability of research success.

Data Sources

Both primary and secondary data were collected for this study. Secondary data on domestic annual consumption and production of tomato were obtained from the Bureau of Agricultural Statistics. Primary data used in the simulation model were obtained from interviews with scientists, industry/market experts and selected tomato farmer focus discussion groups. These interviews and surveys were conducted from April to June 2005. The scientists interviewed were from the IPB-UPLB and were involved in the Philippine MVR tomato program. Interviews with four industry experts and four farmer focus group discussions were held in four major tomato production provinces, namely: (1) Ilocos Norte, (2) Bukidnon, (3) Pangasinan, and (4) Nueva Ecija.

Base Model Assumptions and Parameter Values

Information gathered from both primary and secondary sources were used to develop base model assumptions of a likely research and adoption profile for an MVR tomato variety in the Philippines. The base model assumptions were adopted for the parameters used in the economic surplus model: (1) research lag, (2) expected yield gain, (3) expected change in variable costs, (4) own price elasticities, (5) adoption rate and ceiling, (6) probability of research success, (7) technology depreciation, (8) projected consumption and production levels, (9) prices, and (10) research costs. Finally, the most important assumption considered for MVR tomato is that the multiple virus resistance will be incorporated into a variety that already possesses the desired horticultural traits demanded by the market.

Research lag and expected yield gain

Scientists were asked by what year MVR tomato will most likely be released in the Philippines, and also about expected yield changes. One way to estimate the potential yield gain from introducing a resistant trait into a crop is to equate it with the crop loss avoided from the constraint that is being targeted. Unfortunately, there are no published yield loss studies on TYLCV and CMV. Virology studies on local strains of TYLCV and CMV are also still at the initial stages of research. As such, scientists were asked to provide their best yield change estimates based on their knowledge and experience. From the interview results, yield gain expectations were modeled using a triangle distribution, where the minimum yield gain used was 58 percent; maximum yield gain, 95 percent; and most likely yield gain was 67 percent.

Expected change in variable input costs

A national survey by the Foundation for Resource Linkage and Development (FRLD, 1995) found that over 90 percent of tomato farmers in the Philippines spray chemicals to control pests at least once or twice during seed sowing and after seedling emergence. Transplanted seedlings are subjected to even more frequent spraying schedules. These would include spraying at least once during the growth and fruit development stages and twice a week at the flowering and fruit setting periods when the pest population seems to increase significantly. Based on interviews with farmers and observations by scientists and industry experts, the whitefly vector of TYLCV is extremely difficult to control once its population has increased in farmers' fields.

The scientist-respondents stressed that MVR tomato would not eliminate the need for pesticides, and that MVR variety release and adoption should be coupled with integrated pest management (IPM) to ensure judicious use of chemicals by farmers. The scientists expect that MVR tomato adoption would reduce pesticide application by 20 to 75 percent, which will in turn relate to the national average cost and returns for tomato production (Table 1) as a change in marginal cost, with a range of 4 to 11 percent, and a mean of 10 percent.

No assumption was made on the premium that private seed companies would charge for releasing and distributing an MVR tomato variety. However, industry experts felt that the price of an MVR tomato variety would cost about the same as their tomato hybrid seeds.

Elasticities of supply and demand

Price elasticities measure the responsiveness of quantity demanded or supplied to changes in price (percent change in quantity for a percent change in price). Price elasticities of demand for agricultural food crop commodities are relatively price inelastic (unresponsive). Burleigh and Black (1999) estimated the own price elasticity of demand for tomatoes to be around -0.412 and the aggregate for vegetables in the Philippines to be around -0.553; Aure (1982) estimated the own price of elasticity of demand for tomatoes to be around -0.28 to -0.32. For this study, a triangle distribution is assumed for the own price demand elasticity with -0.3 being the minimum, -0.6 being the maximum, and -0.45 being the mean value.

Table 1. Average cost and returns for tomato production in the Philippines, 2003

	Value (PhP)
CASH COST	46,088
Seeds/planting materials	637
Fertilizer	12,614
Pesticides	11,193
Hired labor	14,112
Land tax	156
Rentals: Land	867
Machine, tools, equipment	282
Fuel and oil	748
Transport of inputs	365
Irrigation fee	20
Interest on crop loan	172
Food expenses	1,450
Repairs	3,102
Other production costs	370
NON-CASH COST*	1,875
IMPUTED COST**	13,910
ALL COSTS	61,873
GROSS RETURNS	104,633
NET RETURNS	42,760
Cost per kilogram (PhP)	6.92
Yield per hectare (kg)	8,943
Farm-gate price (PhP/kg)	11.70

Source: BAS (2004)

* Includes seeds/planting materials, labor paid in kind, landlord and harvester's share, and lease rental

** Includes operator and family labor, exchange labor, depreciation, interest on operating capital, rental value of owned land

There are no published data on the price elasticity of supply for tomatoes in the Philippines. Literature surveyed from other countries included Howitt and Msangi (2002) who reported supply elasticities for tomato in California to be from 0.56 to 0.71, a relatively inelastic supply response due to the prevalence of contract farming. The closest approximation of supply elasticity values for this study was taken from Coxhead et al. (1999), who estimated a crop acreage response of 0.98 for vegetables in the Southern Philippines. Actual supply elasticities may be closer to, if not higher than 1, given that many tomato farmers grow other vegetable crops that utilize similar cultural practices, thus making it easy to shift out of tomato to other crops, depending on price and season. For the purpose of this study, a range of possible price elasticities from 0.5 to 1, with 0.75 as the mean, was assigned.

Adoption rate and ceiling

Industry expert-respondents reported that from their experience, virtually all the farmers within their service areas would adopt an improved tomato variety within two years. They cite the short production cycle of tomato as the major factor for the ease in rapidly growing and multiplying seed for dissemination. The experts expect that virtually all tomato farmers within their area will adopt an MVR tomato variety if and when it is released, especially given the current and increasing widespread damage brought about by TYLCV infections.

In deciding the adoption ceiling, the fact that the MVR tomato program is targeting tomato varieties of the salad/table type, rather than the processing type (those used to make ketchup and tomato paste), was taken note. Unfortunately, there are no statistics available to accurately determine how much area is planted to each type of tomato. Thus, for the base model, we assumed an adoption ceiling of 70 percent, achieved by the beginning of the third year after MVR tomato release. This estimate was based on an approximation of the area grown to salad type tomatoes in the Ilocos region and in Bukidnon, which together account for about 30 percent of the national tomato growing area. In these two areas are the major domestic tomato ketchup and paste processors that require processing type tomatoes.

Probability of research success

The scientist-respondents defined “probability of research success” as the probability that research would successfully generate the technology, and release a seed variety that produce the expected yield gain. All the scientists agreed that the technology needed to develop MVR tomato has been established with complete certainty. The uncertainty lies in whether or not the MVR tomato variety, developed by both the World Vegetable Center and IPB-UPLB, would be sufficiently resistant to local strains of TYLCV and CMV. Based on the information elicited from the scientists, the range of research success expectations was modeled using a triangle distribution where the conservative expectation for research success was estimated at 0.58, an optimistic expectation was set at 0.87, and the most likely level of success set at 0.74.

Technology depreciation

Given the dynamic variation and mutations that occur in virus strains, the scientists were asked to project the durability of resistance of an MVR tomato variety after release. All of those interviewed expected that the resistance would begin to break down by the third year after the initial release. The scientists based their assessment on past experience and observations given the lack of published studies. They assumed that a 10 percent annual depreciation rate in the host plant resistance, after the third year of release, would be a reasonable approximation. The expected depreciation rate was also used to determine the economic time horizon to be used in evaluating MVR tomato adoption. The estimated depreciation rate would suggest that the effective lifespan for MVR tomato would be until its resistance was completely degraded. In the case of the base model, the effective life span of the technology would be from 2011 to 2022. In view of the anticipated breakdown of resistance, the scientists further added that it is plausible to consider that MVR tomato research will continue after the first year of release, in order to develop a replacement for the initial variety within five years.

Projected production and consumption

Consumption, production, and tomato area in the Philippines fluctuate from year to year. Thus, assuming a trend in the base model for each of these variables may not result in estimating a realistic outcome. Instead, this study used *BestFit 4.5* to fit the statistical data for each variable from the last 10 years to a normal distribution. As a result, a normal distribution for tomato area was assumed with a mean of 16,855 ha and standard deviation of 788 ha. For production, a normal distribution was assumed with 152,690 mt mean and 11,010 mt standard deviation. Finally, for consumption levels, a normal distribution is assumed with a mean of 120,971 mt and a standard deviation of 11,187 mt.

Prices, exchange rate and discount rate

This study discounted at 5 percent the future streams of benefits and costs to 2003 USD values. The average farm-gate price in the Philippines for fresh tomatoes in 2003 was computed at PhP11,700/mt or USD215.43/mt (using the 2003 average USD1.00 = PhP54.31).

Research costs

The ABSPII provides a significant share of the funding for the MVR tomato project in the Philippines, whose implementation began in 2005. IPB-UPLB provides an annual counterpart funding. The scientist-respondents were asked to provide an estimate of research costs until the expected first year of commercial release. The estimates were based on actual and projected annual budget requirements. In 2005, the amount budgeted for the MVR tomato project was roughly USD62,000, of which USD32,000 came from IPB-UPLB and USD30,000 from ABSPII. For 2006, an estimated total of USD82,000 was requested, but will revert back to USD62,000 for the remaining years until the MVR tomato variety is released.

For the scenario where maintenance research is simulated to take place, an annual budget of USD32,000 is assigned over a period of five years, from the time maintenance research first takes place, until the fifth year when the replacement variety is released.

Results and Discussion

Base Model Results

Table 2 presents the expected net present value (NPV) of economic benefits from adopting MVR tomato in the Philippines. The average net economic benefits expected from adopting MVR tomato in the Philippines is USD62 million. The expected benefits range from USD49 million to USD77 million. The lower estimate is still significant relative to the estimated discounted total research costs of USD375,082.

Table 2. Net present value of change in producer surplus, consumer surplus and total surplus from adopting MVR tomato (in USD, discounted at 5%), Philippines

	Mean	Lower bound	Upper bound
Producer surplus	43,430,131	36,618,059	52,119,858
Consumer surplus	18,777,913	13,031,709	25,707,062
Total surplus	62,208,044	49,649,768	77,826,920
Net economic benefits	61,867,833	49,309,560	77,486,712
Producer share (%)	69.8	73.8	67.0
Consumer share (%)	30.2	26.2	33.0

If research costs are not taken into consideration, the expected mean present value of the total economic benefit would have been USD62.2 million. Disaggregating this change in gross economic surplus, the mean present value of the changes in producer surplus and consumer surplus are USD43.4 million and USD18.8 million, respectively. Tomato producers would receive 70 percent of the benefits while consumers the remaining 30 percent.

Other Scenarios

Six other scenarios were run using the economic surplus model. Tables 3 and 4 present the mean NPV results and their difference from the base model for each of the six scenarios. The base model assumed that MVR tomato would most likely be released in 2011. In order to determine the impact of an early or delayed MVR tomato release, a simulation was run where MVR tomato is released one year early in 2010 and one year later in 2012. The benefits of releasing the MVR tomato variety one year early is 5 percent more than the benefits of releasing the MVR tomato in the base year of 2011 (Table 3). Releasing MVR tomato in 2012 instead of in 2011 would meanwhile result in economic benefits 5 percent lower than those in the base year.

Table 3. Net present value (in USD) of changes in producer surplus, consumer surplus and total surplus (discounted at 5%) for different dates of MVR tomato variety release

	Base model: MVR tomato release in 2011	MVR tomato release in 2010	MVR tomato release in 2012
Producer surplus	43,430,131	45,660,024	41,361,738
Consumer surplus	18,777,913	19,753,525	17,885,825
Total surplus	62,208,044	65,413,549	59,247,563
Net economic benefits	61,867,833	65,113,305	58,869,290

The scientist-respondents reported that they have only just begun to study the variations of local TYLCV and CMV strains, and how they will mutate after the introduction of MVR tomato. They expect that maintenance research will continue after the first MVR tomato variety is released, in order to address any eventual breakdown in the host plant resistance. This research would imply that funding would still be needed after the initial release, in contrast to the base model scenario where research funding ends as soon as the first MVR tomato variety is released. A scenario was run with additional funding and the mean value of the net economic benefits was estimated at USD88 million (Table 4). This value is 42 percent higher than the base model value, and would suggest a significant incentive for MVR tomato research to be maintained after the initial varietal release.

To provide an upper bound estimate of the potential benefits that can be derived from adopting MVR tomato, two “favorable” or “optimistic” scenarios were simulated. The first scenario assumed that the average yield loss in farmers' fields from combined TYLCV and CMV infections is 100 percent (therefore a 100 percent yield gain if MVR tomato was adopted). The second scenario assumed that MVR tomato would be completely adopted by all tomato farmers in the Philippines, therefore assuming a 100 percent adoption ceiling. The former scenario gave an estimated mean NPV of USD83.9 million or 36 percent greater than the base model NPV. The latter scenario meanwhile gave an estimated mean NPV of USD80 million, a value 29 percent greater than the base model NPV (Table 4).

Table 4. Net present value (in USD) of changes in producer surplus, consumer surplus and total surplus (discounted at 5%) for three scenarios

	Base model: (2011)	Continued research	100% yield change	100% adoption
Producer surplus	43,430,131	61,556,901	58,801,271	56,027,601
Consumer surplus	18,777,913	26,641,308	25,427,641	24,236,359
Total surplus	62,208,044	88,198,209	84,228,912	80,263,959
Total surplus - research costs	61,867,833	87,768,693	83,888,702	79,923,749

Table 5. Net present value of change in producer surplus, consumer surplus and total surplus when varying supply and demand elasticities (USD million)

	Base	ES = 1	ES = 0.5	ED = 0.3	ED = 0.6
Producer surplus	43.4	34.8	57.8	47.1	40.8
Consumer surplus	18.8	11.3	34.5	14.2	22.7
Total surplus	62.2	46.1	92.4	61.3	63.5
Net benefits – research costs	61.9	45.7	92.0	61.0	63.2
Producer share (%)	69.8	75.5	62.6	76.8	64.2
Consumer share (%)	30.2	24.5	37.4	23.2	35.8

We simulated one scenario with the price supply elasticity fixed at 1 throughout the evaluation period, and another scenario with the supply elasticity fixed at 0.5. The results shown in Table 5 indicate that supply elasticity, or the responsiveness of supply to a change in price, has a large impact on the results.

When the elasticity of supply is set to 0.5, the estimated net present value is USD92 million. With it set at 1, the net present value is USD46.3 million. In contrast, the results are little affected by the demand elasticity assumption, or the responsiveness of demand to a price change.

Limitations of the Study and Areas for Further Research

The adoption estimates in this study are highly uncertain. In addition, the premium that seed companies might charge for seed costs, if they decide to be heavily involved in the marketing of hybrid MVR tomato seed, should be explored. However, industry experts perceive that there might not be much of an incentive for seed companies to invest heavily in seed distribution because tomato farmers tend to buy seeds only once when a new variety is introduced, and then save seed for subsequent seasons. This is true even for farmers who buy hybrid seed and other farmers who source their seed from other farmers. As such, whatever is the farmer's method of acquiring seeds, the tomato's short production cycle allows a variety to be quickly diffused in a given area.

Others may argue that some assumptions in our model are too optimistic or pessimistic. As more information becomes available, especially in terms of the efficacy and durability of the MVR tomato to local strains of TYLCV and CMV, then it will be possible to gain a clearer picture of the potential impact of MVR tomato adoption in the Philippines. Nevertheless, the study clearly shows that resource-poor tomato farmers in the Philippines stand to gain significantly if MVR tomato can be successfully released and is adopted.

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Chapter 6

Costs and Benefits of Multiple Virus Resistant Tomato in Indonesia

M. Ameriana

Introduction

Background

Tomato is a high priority vegetable in Indonesia, with continued high demand prompted by the growth of the food industry (Ditjen Tanaman Pangan dan Hortikultura, 1999). Tomato is grown in 31 provinces in Indonesia, with West Java being the most important production center contributing 60–70 percent of the national production. During 1999–2003, the average area under tomato was 46,178 hectares, producing 339,110 tons (Adiyoga et al., 2004). Tomato can be grown at various elevations from lowland (below 200 m above sea level) to highland (above 700 m above sea level), but it is mostly grown in the highlands.

Tomato productivity in Indonesia is low at about 7.3 tons per hectare (t/ha) due to insects and diseases, resulting in considerable yield loss. Farmer surveys indicate that the highest yield loss in the wet season is caused by late blight disease, and by a virus in the dry season.

The viruses that most frequently attack tomato are tomato leaf curl virus (ToLCV) and cucumber mosaic virus (CMV). In most cases, both viruses attack at the same time. Crop loss caused by ToLCV ranges between 60 and 100 percent (Mazyad et al., 1979; Gunaeni et al., 2001; Freitas et al., 2002; Hartono, 2005), and losses due to CMV can reach up to 100 percent (Prabaningrum et al., 1999). Yield losses depend on plant age at the time of the onset.

ToLCV in Indonesia first infested hot pepper in 1992, and affected tomato only in 1996 (Duriat et al., 2004). The spread of ToLCV both on hot pepper and tomato is rapidly growing. A 2002-2003 survey showed that many tomato production centers suffered from ToLCV incidence, covering between 30 and 100 percent of the total area. In 2005, incidence rate was reported to have expanded to 60–100 percent. These statistics indicate that virus-caused disease of tomato is a serious problem.

ToLCV is a Gemini virus spread by whitefly (*Bemisia tabaci*), biotypes A and B. ToLCV is highly variable, evolving various strains that render ineffective to previously known resistance sources. CMV, a cucumo virus, is transmitted by aphids (*Aphis sp.*). Whitefly can survive in all seasons, particularly in the dry season (Duriat et al., 2004). One single whitefly is able to infect at the expansion rate of the vector population (Mansour and Al-Musa, 1992).

A number of methods have been recommended to control both virus diseases, among others, cultural practices such as roguing, intercropping, avoidance, use of barriers and crop residue disposal, combined with the use of pesticides to control the vectors, which have been largely ineffective in the case of whiteflies. The use of mulch, irrigation, sanitation, and resistant varieties are also recommended (Csizinky et a.l, 1995; Hartono, 2005). However, a farmer survey indicated that the use of a resistant variety would be the most effective and optimal control for viruses.

No commercial tomato variety has been found to be highly resistant to both ToLCV and CMV. If there was one, it is likely that farmers would positively respond to it, particularly if it were a high yielding variety. There are two ways to produce a variety resistant to viruses: conventional and biotechnological. The former is more time consuming (ISAAA, 2003) and also constrained by the difficulty in obtaining the resistant gene, leaving little choice but to use biotechnology.

Developed countries have long adopted transgenic crops and an increasing number of developing countries have recently begun adopting them (ISAAA, 2008). In Indonesia, however, transgenic plants have not been well accepted. The planting of *Bt* cotton in Sulawesi was strongly protested, particularly by NGOs. Nevertheless, biotechnology research continues, including that on social impacts. In the case of multiple virus resistant (MVR) tomato, biotechnology-assisted breeding research is currently being conducted along with a study of its potential socioeconomic impact. This study projects the extent to which a transgenic tomato variety would provide economic benefits to growers (farmers) and consumers.

Problem Statement

Indonesia is an agrarian country with almost 60 percent of the population dependent on agriculture. However, farmers still face problems such as low productivity and high pest incidence. Thus, technological breakthroughs through research are important. Research may be considered successful if it offers a solution to a problem faced by farmers as well as economically beneficial to both farmers and consumers.

As noted earlier, ToLCV and CMV on tomato are serious problems in Indonesia for which a transgenic MVR tomato variety is being sought. However, in a developing country such as Indonesia, biotechnology research is not as advanced as in a developed country, and requires a high level of financial and human investment. There are also serious debates between proponents and opponents of transgenic products, mainly centered on their potential negative impacts on community health and environment, as well as socioeconomic impacts.

One issue that is important to address is the extent to which a transgenic variety can give economic benefits, and how these benefits would be distributed. It is also essential to assure environmental safety and to examine the implications of biotechnology for agricultural research policy in Indonesia.

Objective

The specific objective of this study is to assess the economic and environmental benefits and costs of developing and commercializing transgenic MVR tomatoes in Indonesia.

Methodology

Data Sources

Table 1 presents the data required for this study and their respective sources.

Table 1. Data required in the study and their sources

Data required	Data sources*
Prices, quantities, trade (four years)	1
Current production practices (including pesticides)	1, 2
Yields, input costs	1, 2
Crop losses, potential yield gains	1, 2, 3, 4

Data required	Data sources*
Varieties	1, 2, 4
Technical probability of success	3
Seed industry (how are seeds commercialized)	4
Time lags - research, regulatory + costs, intellectual property	3, 4
Elasticities	1
Market adoption	4
Market probability of success	4
Gene flow, biodiversity, unintended effects	1, 3

* Information/data sources:

1 : published
2 : farmer survey
3 : scientist interview
4 : industry expert interview (including private sector, extension workers and regulators)

The study, conducted from February to July 2005, consisted of reviews of published studies, collection of secondary data, farmer group discussions (FGDs), a farmer survey, scientist interviews, seed company interviews, extension worker interviews, and data confirmation seminars. The FGDs relating to virus incidence on tomato took place in the first week of May 2005 in Garut and Lembang and involved a number of farmers. Based on the FGD responses, a brief farmer survey was designed and conducted in the third week of May 2005 in Garut sub-district. Ten farmers were interviewed using a structured questionnaire. The survey of scientists was conducted by interviewing researchers and lecturers, several working in biotechnology, especially in tomato.

Economic Model

This *ex-ante* impact assessment compared the situations with and without MVR tomato research to establish its potential socioeconomic benefits. In the scenarios, the biotechnology research started in 2005, and is expected to produce MVR tomatoes at least five years in the future. This study used an economic surplus model to evaluate the impact of the new technology on welfare as described in Chapter 2 and in Alston et al. (1995) and Ellis (1992). Since tomato produced in Indonesia is mostly consumed in the domestic market, the economic surplus model in this study assumed a small closed economy.

Seed Premium

The technical process of developing the MVR variety consists of cross-breeding the non-transgenic ToLCV-resistant variety with the transgenic CMV-resistant variety. This cross can yield four possibilities: 1) a transgenic hybrid variety, 2) a transgenic open-pollinated (OP) variety, 3) a non-transgenic hybrid variety, and 4) a non-transgenic OP variety. This study evaluated only the transgenic varieties, such that seed premium is assumed only for the transgenic hybrid and OP varieties. Hybrid seed prices are 400-700 percent higher than OP seed prices but despite this fact, seed companies attest that hybrids will be more profitable because of higher productivity. The seed companies also estimated that the price of transgenic tomato seed will be 25-50 percent higher than that of the non-transgenic one. Hybrid tomato seed costs Rp90,000 (USD9.68) per 10 grams, and that of OP is about Rp20,000 (USD2.15) per 10 grams. At a recommended seeding rate of 200 grams per hectare, these translate to Rp1,800,000 (USD193.55) per hectare for hybrids, and Rp400,000 (USD43) for OPs. If transgenic seed is used, then the premium for transgenic seed will cost Rp540,000 (USD58.06) and Rp120,000 (USD12.90) per hectare for the hybrid and OP seed, respectively. In addition, other scenarios are also assumed in our analysis, that is, Rp1,080,000 (USD116.13) for hybrid, Rp240,000 (USD25.81) for OP, and zero premium for both.

Yield increase

Yield loss due to ToLCV and CMV is strongly influenced by the onset of virus incidence. Based on the results of the farmer and scientist surveys, our analysis assumes three yield scenarios. The application of the MVR transgenic variety will reduce yield loss (or increase yield) by up to 60–80 percent. This study assumed a yield increase of as much as 70 percent, and that the yield increase for hybrids will be 40 percent more than that for open-pollinated varities (OPV) of tomato. Thus the scenario for each is as follows:

- Yield loss of 80%: The increase is 56% for hybrid and 40% for OPV
- Yield loss of 60%: The increase is 42% for hybrid and 50% for OPV
- Yield loss of 40%: The increase is 28% for hybrid and 20% for OPV

The above assumptions on the three variables gave 18 scenarios as shown in Figure 1.

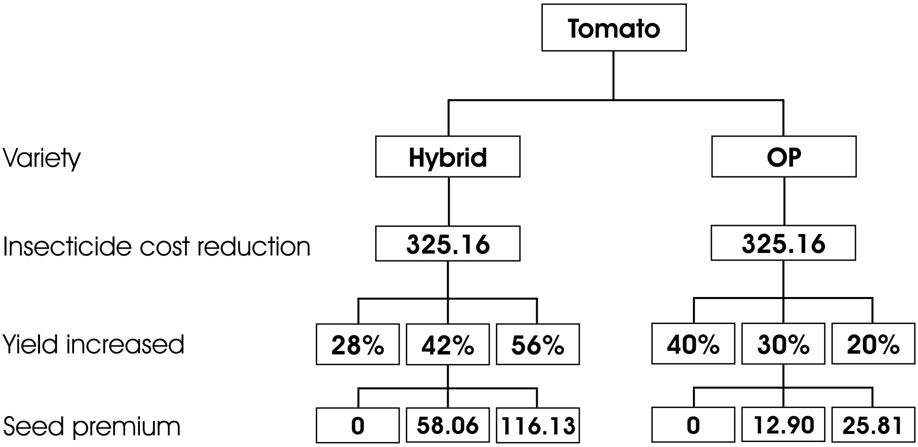

Figure 1. Scenarios for transgenic MVR tomato

Adoption rate

The adoption rate of the transgenic MVR tomato variety will be related to the size of the yield gain, and hence it will be affected by the incidence of ToLCV and CMV as well as by the technology itself. Farmers and scientists reported that the two types of viruses occur at the same time but ToLCV dominates. A 2004 survey of tomato production centers in Indonesia showed that TYLCV covered 30-100 percent of the total area (Duriat et al., 2004), and the incidence range expanded to 60-100 percent in 2005. As such, maximum adoption rate may reach 100 percent. This study estimated adoption rate to reach 80 percent, based on the extent of insecticide cost reduction, and any seed price premium for the ToLCV-resistant transgenic variety. Thus, scenarios contain four groups, each of which has a different maximum adoption rate: 80, 60, 40, and 20 percent. Table 2 gives per unit cost reductions and maximum adoption rates.

Table 2. Maximum adoption rate for each scenario

Scenario*	Cost reduction per unit (%)	Maximum expected adoption rate (%)
OP10 – OP11 – HB13 – OP16 – OP17 – OP18	6.78 – 7.76	80
HB1 – OP4 – OP5 – OP 6- HB7 – OP12 – HB14	5.79 – 6.77	60
HB2 – HB8	4.80 – 5.78	40
HB3 – HB9 – HB15	3.81 – 4.79	20

* OP = open-pollinated; HB = hybrid

The adoption profile for the MVR transgenic varieties is assumed to follow the logistic curve (Figure 2). The transgenic MVR tomato variety is assumed to be released in the sixth year after the research. Adoption will increase until the ninth year, when it reaches the maximum rate, which in turn will be maintained for five years. This means that adoption rate will begin to decline from year 14. New virus-resistant varieties with better resistance or changes in the viruses themselves may cause this decline. Table 3 shows the profile of the 18 categories for simulation.

Supply and demand elasticities

No information was found regarding the supply elasticity of tomato in Indonesia. The value of supply elasticity is thus assumed to be 1, given the nature of the crop. Meanwhile, only one study (Lieshout, 1992) studied the demand elasticity of tomato in Indonesia and found it to be -0.85.

Price

Tomato price in this study refers to the average wholesale price for the period 1999-2003 at Rp1,116,883 (USD120.09) per ton.

Quantity

Secondary data on the quantities of tomato production for 1999-2003 were collected from the Indonesia Statistics Bureau (Badan Pusat Statitik Indonesia). Fresh tomato production for the said period averaged at 339,110 ton per year.

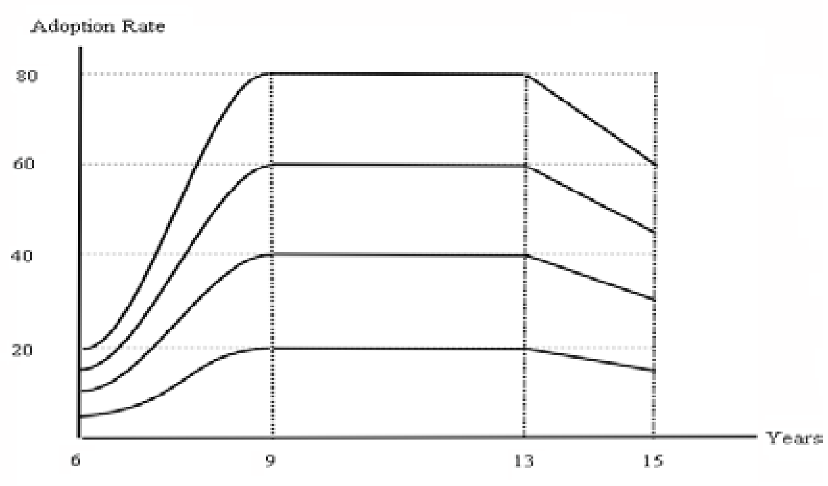

Figure 2. Adoption profiles for transgenic MVR tomato variety

Table 3. Per unit cost reduction and maximum adoption rates for transgenic MVR tomato

Scenario	Yield increase (%)	Seed premium		Cost change		Cost reduction		Maximum adoption rate (%)
		Rp/ha	USD/ha	Rp/ha	USD/ha	Per ha (%)	Per ton (%)	
HB1	56	0		3,024,000	325	9.26	5.93	60
HB2	56	540,000	58	2,484,000	267	7.61	4.88	40
HB3	56	1,080,000	116	1,944,000	209	5.95	3.81	20
OP4	40	0		3,024,000	325	9.26	6.61	60
OP5	40	120,000	13	2,904,000	312	8.89	6.35	60
OP6	40	240,000	26	2,784,000	299	8.53	6.09	60
HB7	42	0		3,024,000	325	9.26	6.52	60
HB8	42	540,000	58	2 ,484,000	267	7.61	5.36	40
HB9	42	1,080,000	116	1,944,000	209	5.95	4.19	20
OP10	30	0		3,024,000	325	9.26	7.12	80
OP11	30	120,000	13	2,904,000	312	8.89	6.84	80
OP12	30	240,000	26	2,784,000	299	8.53	6.56	60
HB13	28	0		3,024,000	325	9.26	7.23	80
HB14	28	540,000	58	2,484,000	267	7.61	5.94	60
HB15	28	1,080,000	116	1,944,000	209	5.95	4.64	20
OP16	20	0		3,024,000	325	9.26	7.72	80
OP17	20	120,000	13	2,904,000	312	8.89	7.41	80
OP18	20	240,000	26	2,784,000	299	8.53	7.11	80

USD1 = Rp9,300

Research Cost

Research to produce transgenic tomato varieties takes at least five years. The scientists and regulators estimated these research costs to total Rp1,625,000,000 (USD174,731) or Rp325,000,000 (USD34,946) per year (see Table 8).

Results and Discussion

Farmer Group Discussion and Farmer Survey

Cropping systems and varieties used

In Indonesia, tomatoes are grown in monocropping or multiple cropping systems (mostly intercropped with hot pepper and cabbage). The common cropping patterns in a year are of:

- cabbage – tomato – potato
- tomato – beans – white cabbage
- (tomato + cabbage) – corn – potato
- potato – cabbage – (tomato + hot pepper)

Table 4 lists the tomato varieties grown by Indonesian farmers and their respective periods of planting, and positive and negative varietial characteristics. The table shows that farmers often change tomato varieties from time to time. For example, Marta and Samina were mostly grown in 2005, while Arthaloka was quite popular during 1996 to 2003. Some farmers reported that Samina is rather tolerant to ToLCV. This change in varieties planted indicates that farmers are responsive to new tomato varieties, and that it will be easy to promote a new variety.

Table 4. Tomato varieties grown in Indonesia, 2005

Varieties	No. of farmers who planted	Period of planting	Positive characteristics	Negative characteristics
Marta	9	2001 – 2005	- high yield - high price - long shelf life - thick flesh	- phytophthora susceptible - virus susceptible - bacterial wilt susceptible
Armina	1	2005		

Varieties	No. of farmers who planted	Period of planting	Positive characteristics	Negative characteristics
Samina	7	2003 – 2005	- virus resistant	
Kosmonot	1	2003		
Precious	1	1996		
TM	4	1999 – 2002	- easy to grow - bacterial wilt resistant	- small fruit - expensive seed
Arthaloka	7	1996 – 2003	- bacterial wilt resistant - high yield - heavy fruit	- virus susceptible
Presto	2	1995 – 1997		
Bonansa	5	1997 – 1999		- light fruit - phytophthora susceptible - difficult to buy seed
California	1	1990		- difficult to buy seed

Pests and pest control

Table 5 identifies the main insects and diseases that attack tomato both in the dry and rainy seasons, ranked based on incidence. In the dry season, viruses (ToLCV and CMV) are the first important problems. In years with very serious virus incidence, yield loss may reach 100 percent. Farmers could not estimate the loss due to ToLCV and CMV separately because they usually infect the crop at the same time. *Helicoperva armigera*, *Bemisia tabaci* and *Spodoptora litura* can also cause serious problems in the dry season. In this case, aside from being a ToLCV vector, *Bemisia tabaci* also acts as a pest. Meanwhile, in the rainy season, late blight is the most dangerous disease, followed by bacterial wilt. Sometimes there are also viruses in the rainy season, but their incidence is not as high as in the dry season.

Farmers observed an apparent correlation between the onset of virus incidence and yield loss (Table 6). The earlier the onset of virus incidence, the higher the yield loss will be. For example, if the onset is at 10-20 days after planting, yield loss can be 75-100 percent. If it is at 71-80 days after planting, yield loss can only be 5-20 percent.

Table 5. Main insect pests and diseases of tomato in Indonesia

Dry Season	Rank	Maximum expected adoption rate (%)	Rank
Virus	1	Ralstonia solanacearum	2
Helicoperva armigera	2	Virus	4
Ralstonia solanacearum	6	Phytophthora infestans (late blight)	1
Bemisia tabaci (whitefly)	3	Rhizoctonia sp	3
Spodoptora litura	4		
Thrip parvispinus	5		

Table 6. Yield loss average based on the onset of virus incidence

Onset of virus incidence (days after planting)	Yield loss (%)
10 – 20	75 – 100
21 – 30	60 – 80
31 – 40	40 – 70
41 – 50	30 – 60
51 – 60	30 – 50
61 – 70	10 – 30
71 – 80	5 – 20

Farmers reported that mechanical control where infected stems are cut off, is the best method currently available to manage viruses (Table 7). If the incidence is very high, farmers pluck out the whole plant. Other control methods include controlled irrigation and the use of a resistant variety. To date, however, farmers have not had a virus resistant variety. The effectiveness of using healthy seed, pesticides and mulch is moderate. Insecticides are the primary means of controlling the vectors, but are also useless once the vectors have infected the crops.

Table 7. Yield loss average based on the onset of virus incidence

Method of control	Very ineffective	In-effective	Moderate	Effective	Very effective
Healthy seeds			✓		
Widening plant distance		✓			
Controlled irrigation				✓	
Resistant variety				✓	
Mechanical control					✓
Pesticide control			✓		
Mulch			✓		

Production costs

Table 8 shows the 2004 tomato production costs in a central production area in West Java. Labor and pesticides respectively account for the highest (34.4 percent) and second highest (31.7 percent) expense items in tomato production.

Three of the 10 farmers interviewed mentioned that in 2004 TYLCV and CMV infected their tomato plants. Table 9 compares the production costs between tomato crops with and without a virus. The yield (ton/ha) difference between tomato crops with and without virus was quite significant at around 135 percent. The insecticide cost for tomato with virus incidence was 34 percent higher than that without virus incidence. The labor cost of pesticide spraying for tomato with virus was 6.3 percent higher. This indicates that to control viruses (the vectors), the farmers increased not only the dosage of insecticides but the frequency of spraying as well.

Table 8. Tomato production cost in Garut District, West Java, Indonesia, 2004

Input	Value (USD/ha)	Percent of total production costs
Seed	105.59	3.93
Organic fertilizer Inorganic fertilizer	250.54 180.82	9.34 6.74
Pesticides: • Insecticide • Fungicide	 224.55 624.75	 8.37 23.89
Sticker	26.78	0.99

Input	Value (USD/ha)	Percent of total production costs
Labor:		
• Men	622.28	23.20
• Women	301.16	11.23
Bamboo	61.33	2.28
Mulch	213.23	7.95
Other	14.98	0.55
Land	50.48	1.88
Total production costs	2,681.90	100.00

Table 9. Tomato yield, pesticide cost, and labor cost in Garut District, West Java, Indonesia, 2004

	Farms with virus incidence (n=3)	Farmers without virus incidence (n=7)	Difference (%)
Yield (kg/ha)	12,505.15	29,392.89	135.04
Pesticide cost (USD/ha)	933.03	814.93	-12.65
Insecticide cost (USD/ha)	294.00	193.75	-34.00
Fungicide cost (USD/ha)	638.94	621.18	-2.78
Labor cost of pesticide spraying (USD/ha)	158.98	148.98	-6.28

USD1 = Rp9,300

Scientist Surveys

Scientists felt that if a genetically-modified virus-resistant crop was to be developed and adopted, yield would be expected to increase by 60-70 percent. The probability of biotech research successfully developing a transgenic MVR tomato with a commercially acceptable level of effectiveness against the virus problem was estimated at 50-60 percent. The scientist-respondents also indicated that, apart from it having some potential for gene flow, the virus resistant variety should have no other significant environmental problems. Table 10 shows the expected research and regulatory costs in developing and commercializing MVR tomato in Indonesia. It should be noted that the food safety cost only refer to nutritional and compositional analysis. Cost of allergenicity and toxicity tests are assumed to be available from technology donor.

Survey of Seed Company Representatives

Seed company representatives felt that farmer adoption of any resistant variety would be high because viruses are such a serious problem. The time required for adoption, however, will be strongly dependent on the variety's potential to overcome the problem. Farmers' preference for a variety is mainly affected by productivity, resistance to pests, and quality. Arthaloka is one of the most frequently adopted varieties, having been used for almost 10 years. At present, the variety that is widely adopted is Marta. Farmers may not care whether the variety is transgenic or not, provided it has high productivity and resistance to TYLCV and to other pests, especially bacterial wilt. Tomato seed produced by one of the biggest seed companies in Indonesia consists of 90 percent hybrids and 10 percent open-pollinated (OP) varieties. Farmers positively respond to hybrids as these are much more productive than the OP varieties. However, the price of hybrid tomato seed may be 5-7 times higher than that of OP seed.

Table 10. Expected costs in developing transgenic MVR tomato and in meeting regulatory requirements, Indonesia

	Cost by Year (USD)				
	1	2	3	4	5
Technology development			80,645		
Regulatory	5,376				
Contained trials	-	2,688	-	-	-
Limited field trial	-	-	32,258		
Multi-location field trial	-	-	-	21,505	
Food safety assessment	-	-	-	26,881	
Apply for commercialization	-	-	-	-	2,150
Total cost over 5 years (USD)			174,731		
Research cost/year (USD)			34,946		

USD1 = Rp9,300

Economic Impacts

The use of transgenic MVR tomato affects three main variables: insecticides, seeds, and yield. Several scenarios were constructed based on these three variables and on the type of variety used (open-pollinated versus hybrid) to illustrate possible impacts of the technology. Table 11 presents the total value of surplus change (in USD) and the net present value (NPV) of the surplus for each scenario.

The NPVs for all the scenarios are positive (Table 11). The research investment is USD34,946 per year or USD174,731 over five years. For hybrids, a scenario of 56 percent yield increase and cost reduction of USD325/ha (scenario HB1) gave the highest NPV, while a yield increase of 28 percent and cost reduction of USD116/ha (scenario HB15) gave the lowest NPV. For OP varieties, a yield increase of 40 percent and cost reduction of USD25/ha (scenario OP6) gave the highest NPV, while a yield increase of 20 percent and cost reduction of USD325/ha (scenario OP16), the lowest NPV.

In addition to yield increase and cost reduction, adoption also affects the increase in the total economic value of the new technology. Scenarios HB1, HB2 and HB3 assumed maximum adoption rates of 60, 40 and 20 percent, respectively, and total surplus changes were USD26,583, USD17.9 million and USD9.0 million, respectively. Scenarios OP4, OP5, and OP6 all have maximum adoption rates of 60 percent and total surplus changes are similar.

Table 11. Projected changes in total, consumer and producer surplus (USD)

Scenario	Yield increase (%)	Seed pre-mium (USD/ ha)	NPV of change in (USD):			NPV of total surplus less R&D cost
			Total surplus	Consumer surplus	Producer surplus	
HB1	56	0	26,583,207	14,369,301	12,213,906	26,431,908
HB2	56	58	17,926,930	9,690,232	8,236,698	17,775,631
HB3	56	116	9,059,657	4,897,112	4,162,545	8,908,358
OP4	40	0	11,625,453	6,284,029	5,341,424	11,474,154
OP5	40	13	17,695,600	9,565,189	8,130,411	17,544,301
OP6	40	26	17,833,539	9,639,751	8,193,788	17,682,240
HB7	42	0	18,677,558	10,095,977	8,581,581	18,526,259
HB8	42	58	12,775,449	6,905,648	5,869,801	12,624,150
HB9	42	116	6,545,119	3,537,902	3,007,217	6,393,820
OP10	30	0	16,010,556	8,654,354	7,356,201	15,859,257
OP11	30	13	16,213,395	8,763,997	7,449,398	16,062,965
OP12	30	26	12,251,107	6,622,220	5,628,887	12,099,808
HB13	28	0	9,712,268	5,249,875	4,462,393	9,560,969
HB14	28	58	11,518,315	6,226,116	5,292,199	11,367,016
HB15	28	116	4,030,619	2,178,712	1,851,905	3,879,319
OP16	20	0	8,524,532	4,607,855	3,916,677	8,373,233
OP17	20	13	8,734,819	4,721,524	4,013,295	8,583,520
OP18	20	26	8,951,052	4,838,406	4,112,645	8,799,753

Table 11 also shows that transgenic MVR tomato can improve economic welfare significantly. The total surplus value by scenario varies from USD6.5 million to USD26.6 million. The change in total surplus is nearly evenly distributed to consumers and producers at a ratio of 54 to 46 percent. Consumers' welfare improves with more of the commodity available at a lower price. Producers' welfare increases due to yield increase and cost reduction. In addition, although selling at a lower price, producers can sell a higher quantity of tomato.

As indicated earlier, the development of a transgenic MVR tomato variety may involve either OP varieties or hybrids. Scientists, however, are not sure which type will be released in Indonesia. For one, the cost reduction for OP is higher than that of the hybrid because of the lower OP seed price. This low seed price has caused all the OP variety scenarios to have high maximum adoption rate (60-80 percent), whereas the rate varies between 20 to 80 percent for the hybrid. The next difference lies in productivity rate. Hybrids can yield twice as much as the OP varieties so that, at the same yield loss levels, hybrids can give a higher yield increase. One of the biggest seed companies in Indonesia reported that, at the moment, 90 percent of the seeds produced are hybrids, and the rest are OP varieties. Despite the higher seed price, farmers prefer hybrids over the OP varieties.

To date, transgenic tomato is not yet produced in Indonesia. Should the technology prove to be successful, the question to be addressed will be who would be responsible for its production. The seed premium (seed mark-up) will indicate profitability for the seed company. In other words, the higher the seed mark-up, the more profitable it will be and the more likely a seed company will become involved.

Environmental Impacts

Farmers primarily use chemical pesticides to control pests. Horticultural producers in Indonesia use chemical pesticides intensively in terms of both spraying frequency and dosage (Udiarto et al., 1995; Rauf et al., 1993; Mudjiono and Nurimah, 1993). Tomatoes are sprayed with as much as 9-10 liters/ha of insecticides and 50-54 kg/ha of fungicides (Ameriana, 2004).

As have been documented in the literature, the negative impacts of using pesticides include, among others, environmental pollution, insect and disease resistance to the pesticides, and chemical residues (contamination) in the produce. Analyses of vegetables sampled from producers, wholesalers, traditional markets, and supermarkets showed that some vegetables contain pesticide residues at the threshold of standardized limit (Adiyoga et al., 2000; Harun et al., 1996; Soeriaatmadja et al., 1993).

The use of the transgenic MVR tomato variety may reduce insecticide use by 70-80 percent, saving approximately 7-8 liters/ha. As such, transgenic MVR tomato variety can contribute to environmental improvement, preventing the development of pest resistance to pesticides, and protecting consumers from chemical residues.

Unintended Effects

The most frequently debated environmental concerns with respect to trangenics relate to gene flow, biodiversity reduction, and harm to non-target organisms. The scientist-respondents in this study indicated that there are environmental advantages and disadvantages in the use of transgenic varieties. The main advantage is reduction in chemical pesticide use, and all its consequent positive impacts as already mentioned above. In addition, the chances of biodiversity reduction and harm to non-target organism are likely to be very small. One disadvantage is the potential occurrence of potentially damaging gene flow, although its probability is below 5 percent. This probability can be overcome by providing a safe distance between the transgenic and the non-transgenic crops.

In general, the scientists who oppose transgenics worry about, among other things, horizontal gene transfer with the potential of creating new pathogenetic bacteria and viruses or other weed species. If the transgenic crop becomes a weed, an indigenous species may be lost (Kathen, 1997). They also worry about new strains developing resistance to herbicides and biopesticides (Wan Ho, 2005; Environmental Health Perspectives, 1996; Braun and Ammann, 2002).

A specific consideration for risk analysis in centers of biodiversity is the assumption that gene flow occurs, as this potentially can occur with all new varieties, transgenic and non-transgenic. Impact analysis should focus on the consequences - not on the probability – that such a gene flow occurs because it almost always does (Kathen, 1997). Just because it occurs, however, does not mean that it causes meaningful damage. The proposed strategy, therefore, would be to characterize the species of concern and on a case by case basis, focus on the impact of the trait to be introduced. In most cases, after gene flow, the unintended altered species do not thrive or even survive and therefore the practical consequences of the gene flow should be assessed.

Conclusion

This *ex-ante* study has shown that transgenic MVR tomato has significant potential economic impacts that would increase economic welfare. Across the various scenarios examined, the value of total surplus varied between USD6.5 million and USD26.6 million. The change in total surplus was found to be distributed to consumers and producers at a relatively even ratio of 54 to 46 percent.

In addition to yield increase and cost reduction, the adoption rate of transgenic MVR tomato affects the increase in the total economic value. A higher maximum adoption rate means a bigger change in total surplus. Transgenic MVR tomato, by reducing the use of insecticides, indeed has the potential to significantly contribute to maintaining environmental quality and minimizing pesticide residues in the products.

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Chapter 7

Costs and Benefits of Transgenic Late Blight Resistant Potatoes in Indonesia

W. Adiyoga

Introduction

Due to their high protein to calorie ratio and short vegetative cycle, potatoes yield substantially more edible energy and protein per hectare and per day than do both cereals and cassava (Horton, 1987). The potato crop's high yield per unit of land area and time is an especially valuable trait in developing areas, such as Indonesia, where the climate permits more than one crop to be grown in the field each year. While the crop was first introduced into the highlands of Indonesia sometime in the 18th century, available statistics show that potatoes were not considered as an important vegetable crop in Indonesia until the 1970s. Since then, potato production and area in Indonesia have expanded rapidly, reaching 1 million tons harvested from about 60-70,000 hectares (ha) annually by the mid-1990s. Indonesia's domestic potato production meets a domestic demand that averages 990,000 tons annually. From 1963 to 2003, production grew at 4.6 percent per year on average (with average planted area growth of 3.0 percent and average yield growth of 1.6 percent). At the demand side, Indonesian consumers prefer potatoes with soft texture, slightly sweet taste and yellowish flesh color (Ameriana et al., 1998). Potato, typically cut up into small pieces and added to a main dish, is consumed by all income groups.

In Indonesia's highland vegetable production system, year-round rainfed production is possible and two to three crops of short-duration vegetables are often grown. Potato, the most important crop of the system, is typically rotated with cabbage or another vegetable during the year. The most recent survey indicated that in highland areas, agriculture contributed three-fourths of total household income, and potato contributed nearly half of agricultural income (Fuglie et al., 2004).

By far, the most important potato variety grown in Indonesia is Granola, a variety released in Germany in the late 1970s and which was introduced into Southeast Asia in the early 1980s. It proved popular in the tropical highlands due to its short growing season (harvested 90-100 days after planting), high yield, resistance to viruses, and acceptance by consumers. It quickly dominated potato production in Indonesia and is grown approximately on 90 percent of the potato area every year. However, Granola is very susceptible to late blight (*Phytophtora infestan*), a devastating fungal disease that thrives in the cool humid conditions found in Indonesia's tropical highlands. Potato late blight widely occurs in the major potato production regions in Indonesia, which represent more than 50 percent of the total planting area. In the said regions, rainfall, temperature and humidity are suitable for potato production, but are also suitable for the occurrence and spread of potato late blight.

The degree of damage from potato late blight is closely related to varietal resistance, soil conditions, weather, and planting practice. The earlier the disease appears during the season, the more serious the damage. The main source of primary infection is through potato seed.

Farmers who grow susceptible varieties, especially during the wet season, must protect their crop by spraying fungicides every two or three days. Farmers may spray their potato crop 20-30 times during a single season. The use of late blight resistant varieties can significantly reduce the number of sprays, but unfortunately most varieties are susceptible to the disease. Populations with general resistance have been generated by breeders at the International Potato Center (CIP, Lima, Peru), and these are being tested in many developing countries, including Indonesia. There are some new moderately resistant cultivars, but highly resistant cultivars are rare.

Recently, genetic engineering is being applied in an attempt to give potato resistance to the pathogen. By placing a gene from a naturally blight-resistant wild potato into a cultivated variety, researchers from the University of Wisconsin-Madison and the University of California, Davis have produced plants that are resistant to a range of blight strains (McDonagh, 2003). The scientists suspected that a four-gene cluster in the wild potato species *Solanum bulbocastanum* was responsible for its resistance to blight. They cloned the genes and spliced one gene into each of four batches of potato plants. When they exposed these new cultivars to blight, one group stayed healthy, suggesting that the gene it received was conferring resistance. The scientists named the gene *Rb*, for resistance from *S. bulbocastanum*. A major resistance gene (*Rb*) has been cloned and transferred into Katahdin (a US potato variety) under the control of the native promoter. Transgenic plants have been field tested in Minnesota, Wisconsin, Washington and, for two years, in Toluca (Mexico) where highly resistant events have been identified. Based on these demonstrations of resistance to all major races of the fungus, it is anticipated that this gene will also be effective in other countries, such as Indonesia, where late blight is an important disease.

Farmers rank late blight as the most important pest problem of potatoes, given its negative effect on yield and income. Also, the consequent high pesticide use can have negative external effects such as water contamination. The worldwide debate over the risks and ethics of transgenic crop use is similarly a concern. However, with limited empirical evidence of benefits and risks from adopting transgenic crops, the debate between critics and proponents of agricultural biotechnology has often been based on beliefs rather than facts (Qaim, 1999). Therefore, an estimation of the benefits that can be expected from the use of late blight resistant transgenic potatoes in Indonesia would provide important economic information to the debate. Furthermore, the information generated by evaluations can be used in research prioritization and in developing effective product deployment strategies. This study assessed the size and distribution of the economic gains generated by the introduction of a late blight resistant potato variety in Indonesia.

Methodology and Data Used

This study employed economic surplus analysis to project economic impacts of a late blight resistant (LBR) transgenic potato variety in Indonesia, following the approach described in Chapter 2. Both primary and secondary data were used in the analysis. Primary data were collected through focused group discussions, scientists survey and an industry experts survey. Secondary data were obtained from various sources, including the Indonesian Central Bureau of Statistics and the Indonesian Ministry of Agriculture. Potatoes in Indonesia are grown mostly for domestic consumption, such that they were modeled as a simple closed economy.

Since field data were not available, cost and return effects of LBR potato were calculated using expert opinion and partial budgeting as compared to current varieties. The key variables in the partial budget are the difference between the per-hectare cost of inputs used in growing traditional varieties and those used for the transgenic technology, the expected yield increase in both cases, and seed price difference between the transgenic variety and the traditional variety (seed premium or seed markup). To account for the uncertainty of the final value of these variables, the analysis was conducted across a range of feasible values. Each combination of values provided a scenario to evaluate the impact of the transgenic variety.

The per-unit cost reductions associated with transgenic varieties were created based on current budget figures for potatoes and the potential advantages of a new genetically-transformed variety.

Change in Pesticide Cost per Hectare

In 2005, the average potato production cost in Indonesia was Rp38,283,500 (USD4,117) per hectare, 28.6 percent (Rp10,927,000 or USD1,175) of which was for pesticides. The cost of fungicides for controlling late blight was estimated to be approximately 75 percent of the total cost spent on pesticides. With transgenic technology, the maximum reduction in pesticide cost can be 100 percent or Rp8,195,250 (USD881). However, the study also considered that additional treatments may still be necessary when very intensive late blight attacks occur. As such, the pesticide cost reduction was assumed at 80 percent or Rp6,556,200 (USD705) and at 50 percent or Rp4,097,625 (USD441).

Seed Premium

One of the most important constraints in Indonesia's potato production is the availability of high quality seed at an affordable price. On average, farmers spend a total of Rp9,127,000 (USD981) per hectare for seed, or 23.8 percent of the total production cost. Considering the farmers' ability to purchase seeds, this study set the seed premium at 0 percent, 15 percent (Rp1,369,050; USD147) and 30 percent (Rp2,738,100; USD294) per hectare.

Yield Increase per Hectare

This study used crop loss estimates due to late blight infestation in Indonesia, reported to be 30-60 percent, to estimate the yield effect of LBR potato. Kusmana (2003) estimated a yield loss of 47 percent for Granola from experimental data. This study assumed yield loss at 30, 40 and 50 percent. Meanwhile, expert-respondents suggest that the use of a LBR potato variety will reduce yield loss by up to 80 percent. Hence, this study estimated potential yield increase at 24, 32 and 40 percent.

Table 1 combines all the above information to create 18 scenarios. The scenarios can be depicted in a decision tree with each decision level corresponding to each of the variables used. The first level on the tree (2nd and

3rd columns) is the base cost per hectare of pesticide use under the traditional technology. The second level (4th and 5th columns) is the decrease in pesticide cost due to the use of new (transgenic) technology. The next two levels (6th to 8th columns) include the different values for percent yield increase per hectare and the seed markup.

Table 1. Transgenic potato scenarios for Indonesia

Sce-nario	Pesticide cost/ha		Pesticide cost reduction/ha		Yield increase (%)	Seed markup/ha	
	Rp	USD	Rp	USD		Rp	USD
P1						0	0
P2					24	1,369,050	147
P3						2,738,100	294
P4						0	0
P5			6,556,200		32	1,369,050	147
P6				704		2 738,100	294
P7						0	0
P8					40	1,369,050	147
P9						2,738,100	294
P10	10,927,000					0	0
P11		1,174			24	1,369,050	147
P12						2,738,100	294
P13						0	0
P14			4,097,625		32	1 369,050	147
P15				440		2,738,100	294
P16						0	0
P17					40	1,369,050	147
P18						2,738,100	294

USD = Rp9,300

Adoption Rates and Adoption Profiles

Adoption rates are crucial because, all other factors equal, they are a major determinant of the magnitude of the change in total economic surplus. Seed companies undoubtedly consider the expected maximum adoption rate when setting seed price markup. Technology adoption rates also increase as the expected net benefit increases, reducing the risk associated with the technology (Mills, 1998). Allowing the maximum adoption rate to vary with the size of the technology's net benefit provides an insight for policy analysis into the trade-off between seed markup and economic benefits.

In the 2003 season, the Granola variety covered about 90 percent of the total potato area in Indonesia. Since late blight is such a common potato disease, this study assumed that 90 percent of the total area is infested annually. The potential adoption rate for the new variety (late blight resistant) is then 81 percent, and maximum adoption rates of 20, 40, 60 and 80 percent were assigned for the simulation exercises. In addition, the study assumed that research takes five years before the new variety is released, such that adoption starts from year six, year seven and so on.

The study evaluated the stream of benefits derived from adopting LBR transgenic potatoes for a 15-year period. Having set a maximum adoption rate according to the expected net benefits, there is still the need to define a proper adoption profile for the period. Alston et al. (1995) suggest linear (trapezoidal) or logistic curve forms for adoption paths on *ex-ante* evaluations, although the linear approach has been used more often in empirical studies (Mills, 1998). This study assumed that maximum adoption rates are reached four years after the technology's release, and that adoption begins to decline after year 15. The slow pace of adoption corresponds to the characteristics of a heterogeneous potato sector, where large-scale and small-scale farmers respond in different ways to the presence of a new technology. This analysis applied the S-curve or logistic curve; Table 2 illustrates the adoption paths.

Table 2. Adoption paths for transgenic potatoes in Indonesia

Year	Maximum expected adoption rate (proportion of producers)			
	80%	60%	40%	20%
2005	0	0	0	0
2006	0	0	0	0
2007	0	0	0	0
2008	0	0	0	0
2009	0	0	0	0
2010	0.20	0.15	0.10	0.05
2011	0.40	0.30	0.20	0.10
2012	0.60	0.45	0.30	0.15
2013	0.80	0.60	0.40	0.20
2014	0.80	0.60	0.40	0.20
2015	0.80	0.60	0.40	0.20
2016	0.80	0.60	0.40	0.20
2017	0.70	0.53	0.35	0.18
2018	0.60	0.45	0.30	0.15
2019	0.50	0.48	0.25	0.13

Adoption rates depend on the profitability of the new technology, which in this study is represented by the proportionate change in input cost per ton. Adoption also depends on the change in pesticide costs per hectare, the seed markup and the expected yield increase assumed in each scenario. Because secondary data linking the profitability of different technologies to the achieved adoption rates were not available, the total range of the proportionate input cost change per ton resulting from the simulation of each scenario was divided into four quartiles, and each quartile was assigned a different maximum adoption rate. The maximum adoption rates range from 20 to 80 percent with 20-point intervals. Table 3 illustrates each scenario with the assumed maximum adoption rates and range of the proportionate input cost change.

Demand Elasticity

Demand for fresh table potatoes in Southeast Asia appears to be relatively inelastic with an own-price elasticity of around -0.17 to -0.22. For Indonesia, Pasaribu (1989) estimated potato own-price elasticity at -0.6 to -0.8. Meanwhile, Fuglie et al. (2002) reported that per capita consumption of fresh table potatoes is much higher than that of processed potatoes and is also likely to show strong growth in the future. They approximated the own-price elasticity of potatoes in Jakarta, Indonesia to be -0.5. Based on these literature reviews, this study used a demand elasticity for potato at -0.5.

Supply Elasticity

Alston et al. (1995) suggest that most long-run supply elasticities are high since in the long-run most fixed factors become variable. The literature review does not provide precise information from which to infer a proper value for the supply elasticity of potatoes in Indonesia. Alston et al. (1995) state that for empirical work related to priority-setting and when data is scarce, supply elasticity can be set at 1, which this study followed.

Prices

In the period 2000-2003, wholesale prices of potatoes in Indonesia averaged at Rp2,100 (USD0.23) per kg. This study then sets the wholesale price constant at Rp2,100,000 (USD226) per ton.

Quantities

Base quantities were calculated using average harvested area and the average yield, which was 63,095 ha and 15.9 tons per ha, respectively, in the period 1995-2003. As such, the base quantity of potato production was set at 1,060,000 tons.

Table 3. Proportionate input cost change per ton and maximum adoption rates for transgenic potatoes in Indonesia

Cost reduction		Yield increase (%)	Seed markup		Group	Scenario	Proportionate change in input cost		Maximum adoption rate (%)
Rp/ha	USD/ha		Rp/ha	USD/ha			Per ha	Per ton	
6,556,200	704	24	0	0	I	P1	0.171	0.138	80
			1,369,050	147		P2	0.135	0.109	60
			2,738,100	294		P3	0.099	0.080	40
		32	0	0	II	P4	0.171	0.130	80
			1,369,050	147		P5	0.135	0.102	60
			2,738,100	294		P6	0.099	0.076	40
		40	0	0	III	P7	0.171	0.122	80
			1,369,050	147		P8	0.135	0.096	60
			2,738,100	294		P9	0.099	0.071	40
4,097,625	441	24	0	0	IV	P10	0.107	0.086	60
			1,369,050	147		P11	0.071	0.057	40
			2,738,100	294		P12	0.035	0.029	20
		32	0	0	V	P13	0.107	0.082	60
			1,369,050	147		P14	0.071	0.054	40
			2,738,100	294		P15	0.035	0.027	20
		40	0	0	VI	P16	0.107	0.076	60
			1,369,050	147		P17	0.071	0.051	40
			2,738,100	294		P18	0.035	0.025	20

Monopolist's Profit

Monopoly profits were calculated using the per-hectare markup estimated in the partial budget for the transgenic varieties, the adoption rate in each year, and the average cropping area estimated above. The adoption area in each year (in hectares) was calculated from the total base area estimated for potatoes, and the corresponding adoption rate in each year given by the estimated adoption paths.

Other Variables

The analysis in this study assumed that the transgenic technology has not been released and the relevant probability of research success is 0.5. Annual research cost for potatoes was assumed to correspond to the expected yield increase. Scientist-respondents estimated a research cost of Rp350 million (USD37,634) per year until the technology is released at the sixth year (Table 4).

Table 4. Parameter values for the computation of changes in economic surplus in potato production in Indonesia

Parameter	Description and value
Year	Annual benefits were projected for 15 years after research commences, 2005-2019 (t = 1,2,..,15)
Supply elasticity	Set at 1
Demand elasticity	Set at -0.5
Proportionate yield change	In this study, 30, 40 and 50% yield loss were used. With LBR potato potentially reducing yield loss up to 80%, the estimates of yield increase, used were 24, 32 and 40%, respectively.
Proportionate change in input cost per hectare	Pesticide cost reduction was set at Rp6,556,200 (USD705) (80%) and Rp4,097,625 (USD441) (50 percent). Seed premium was at 0% (Rp0), 15% (R1,369,050; USD147) and 30% (Rp2,738,100; USD294) per hectare. Thus, the proportionate changes in per-hectare input cost for 80% pesticide cost reduction were 0.171; 0.135 and 0.0997, and 0.107; 0.071 and 0.0355 for 50% pesticide cost reduction.
Probability of research success	Since the analysis assumed that the technology has not been released yet, the probability of research success is set at 0.5.
Adoption rate	The assigned maximum adoption rates were 20, 40, 60 and 80%. Research takes five years before the new transgenic variety is released, so adoption starts from year six, and so on.
Wholesale price	Wholesale prices for the period of 2000-2003 are averaged, giving a mean value of Rp2,100,000 (USD226) per ton.
Production quantity	The pre-research quantity is constant, equal to the base production quantity of 1,060,000 ton.
Annual research cost	The estimated annual research cost for potatoes is Rp350 million (USD37,634) per year.

Results and Discussion

Farm Survey Results

Potato is grown throughout the highlands of Indonesia. During the 1995-2003 period, Indonesia's potato area ranged from a low of 50,189 ha (1997) to a high of 73,069 ha (2000). In the same period, production ranged from a low of 813,368 tons (1997) to a high of 1,321,117 tons (2002), and annual national yields averaged at 15.94 t/ha, which was close to the world yield average of 16 t/ha.

In some provinces, however, potato yields exceeded the national average. For example, West Java, which accounts for 37.2 percent of national production, reported an average yield of 18.62 t/ha in 2003. Also some regencies of West Java reported potato yields far exceeding the national average, with the highest yield of 20.5 t/ha observed in Pangalengan. A group of farmers in Pangalengan, who were interviewed during the field visit, reported yields of 25-28 t/ha.

Provincial Distribution of Production

In 2003, the three most important potato producing provinces in Indonesia accounted for about 72.9 percent of national production – West Java, 37.1 percent; North Sumatra, 23.3 percent; and Central Java, 12.5 percent. Six other provinces (Aceh, West Sumatra, Jambi, East Java, South Sulawesi and North Sulawesi) are also considered as major potato producing areas. In 2003, the combined output of these nine provinces accounted for over 99 percent of Indonesia's national potato production.

Potato Varieties Grown

Key informants estimated that 91 percent of the annual potato crop is planted to the Granola variety, with farmers refreshing their seed stock every four to five planting seasons. About 6 percent of the total potato area is sown to processing varieties such as Columbus, Atlantic and Panda. The rest of the potato area is planted to an assortment of other varieties, including a popular farmer selection in East Java known as Ritex.

After two decades of rapid growth, by the late 1990s, area planted to potatoes in Indonesia had stabilized at around 70,000 hectares per year. Assuming an average seeding rate of 1.5 t/ha, this implies a need for about 105,000 tons of potato seed annually. Several competing sources supply this critical input to Indonesian farmers. One important source is the informal seed system, where potato seed is saved from the previous harvest or purchased from other farmers. In addition, three other sources of 'improved' or 'quality' seed exist.

First are imports of certified seed of foreign-bred varieties. The second sources of improved seed are private companies with tissue culture facilities supplying disease-free plantlets or mini-tubers. A third source of improved seed is a newly established public-sector certified seed system located in West Java.

Insects and Diseases

Key informants at the Indonesian Research Institute for Vegetables (IVegRI) reported that late blight remains to be an important constraint to higher potato yields in the country. This disease may reduce farmers' yields by 20-50 percent and also reduce tuber quality. Only a limited number of studies have been carried out in Indonesia to quantify the incidence and impact of this disease on potato yields. Kusmana (2003) evaluated 21 potato clones and found that yield losses due to late blight ranged at 10-90 percent, compared to the non-inoculated control. Granola, the most popular potato variety used by farmers, lost as much as 47 percent of its yield. Estimated potato yield loss caused by late blight provided by farmer-respondents varied depending on the date of onset of the disease. Majority of the farmer-respondents provided higher yield loss estimates when the disease attack occurs early in the season. Yield loss of as high as 75 percent was reported when late blight attack occurs at 20-30 days after planting (DAP) while the maximum yield loss estimated at 71-80 DAP was 10 percent (Table 5).

Table 5. Estimated potato yield loss caused by late blight from farmer focused group discussion

Farmer-respondent	Yield loss (%) when late blight attack occurs at:					
	20-30 DAP	31-40 DAP	41-50 DAP	51-60 DAP	61-70 DAP	71-80 DAP
Grower 1	10	20	30	50	40	10
Grower 2	75	-	50	-	20	10
Grower 3	0	0	30	30	25	15
Grower 4	50	-	20	-	5	-
Grower 5	20	50-60	50-60	40-50	20-25	5-10
Grower 6	60	40	30	20	10	-
Grower 7	70	40-60	40-60	30	20	5

Farm Size, Land Tenure and Cropping System

In the highland vegetable production system, year-round rain-fed production is possible, and two to three crops of short-duration vegetables are often grown. Potato, the most important crop in this system, is typically rotated with cabbage or another vegetable during the year. Results of the most recent farm survey show that small farms dominate highland vegetable production in Indonesia. The average size of a potato farm is about 1 ha, with few farms over 2 ha.

In general, the land market is well developed in the highland vegetable production areas and cash rent predominates. About 60 percent of the area planted to potatoes in West Java was rented, double the percentage in the other provinces surveyed. In all provinces except West Java, there were potato growers who are landless households renting land to grow potatoes. According to the survey, about 6 percent of the potato growers owned no cropland, about half owned their cropland and the rest used both owned and rented land to grow crops. A household on average owned 1.16 ha of cropland with an additional net rental area (area rented minus area rented out) of 0.34 ha for a total land operated of 1.50 ha.

Enterprise Budgets: Inputs and Yields

Table 6 presents the average costs and returns for potato production in Indonesia in 2004. The farm budget shows that purchased inputs accounted for 72.3 percent (Rp26,672,000 or USD2,868 per ha) of total costs. Total labor requirements averaged at 923 person-days/ha, and hired labor accounted for 18.1 percent (Rp6,917,000 or USD744 per ha) of total costs. Based on the average yield of 28.9 t/ha and a farm-gate price of Rp1,926.50 (USD0.21) per kg, average farm income was estimated at Rp17,371,200 (USD1,868) per ha. It should be noted though that the farm budget varies considerably with respect to specific cost items, most likely due to different definitions/categories used to report specific cost items, different reporting years, and the manner that each budget values family labor. Table 7 presents the details of pesticide use and costs.

Table 6. Per-hectare costs and returns analysis of potato production, Pangalengan, West Java, Indonesia, 2004

Description	Quantity	Value (Rp '000)	% of Total
INPUTS			
Labor (person-days)			
Land preparation	276.29	2,072	5.41
Applying inputs	185.85	1,393	3.64
Planting	38.57	289	0.75
Harvesting	92.86	696	1.82
Other operations	329.07	2,467	6.44
Sub total	922.64	6,917	18.06

Description	Quantity	Value (Rp '000)	% of Total
Material Inputs			
Seed (kg)	1,825	9,127	23.84
Fertilizers (kg)			19.89
Urea	317	349	0.91
Zinc ammonia (ZA)	397	476	1.24
Super phosphate (SP)-36	397	635	1.66
Potassium chloride (KCl)	317	571	1.49
Complete (NPK) 15-15-15	952	1,524	3.98
Organic fertilizer	25,400	4,063	10.61
Pesticides		10,927	28.65
Sub total		27,672	72.28
Other Costs			
Land rent		2,381	6.22
Others		1,313.5	3.44
Sub total		3,694.5	9.66
Total Expense		38,283.5	100.00
OUTPUT			
Production (kg)	28, 889		
Price (Rp/kg)	1,926.50		
Total Revenue		55,654.7	
GROSS FARM INCOME		17,371.2	
INCOME OVER EXPENSES		61.4%	

Table 7. Estimated cost of fungicides and insecticides used in potato production, dry and rainy season, Pangalengan, West Java, Indonesia, 2005

	Season	Other costs (%)	Pesticide costs (%)	Cost of fungicides to control late blight (%)	Insecticide costs (%)
Grower 1	Rainy	65	35	25	10
	Dry	65	35	10	25
Grower 2	Rainy	60	40	30	10
	Dry	60	40	10	30
Grower 3	Rainy	60	40-50	20	20-30
	Dry	70	30	10	20
Grower 4	Rainy	78	22	18	4
Grower 5	Rainy	60	40	30	10

Marketing and Trade

Commercial potato farmers typically harvest their crop and sell it to middlemen (traders) who visit their farm. The middlemen generally then sell to large wholesale markets located in major urban areas. On the other hand, some farmers directly market their crop to vegetable sellers in nearby public markets, or have contracts to supply supermarkets (for table potato) or food processing company (for processing potato). Most of the potato produced in Indonesia is consumed domestically. Import and export statistics indicate that Indonesia has imported/exported only small quantities of potatoes (Adiyoga et al., 1999; Adiyoga et al., 2001).

North Sumatra accounts for more than 90 percent of Indonesia's total potato exports (table potatoes for the fresh market). Nearly all of Indonesia's potato exports are destined for either Malaysia (about 70 percent) or Singapore (30 percent). Indonesia's quantity of potato exports peaked in 1995 at 103,050 tons, which was nearly 10 percent of total domestic production. Exports subsequently fell to about a third of this level. Between 1997 and 2000, exports were relatively stable averaging 30,598 tons/year, or about 3.2 percent of domestic production (Adiyoga et al., 2001).

Meanwhile, most potato imports (1997-2000) are in the form of processed products, with frozen French fries accounting for nearly three-quarters of the total value of potato imports. Most of these imports originate from North America. Other processed potato products such as starch and flakes used in food processing accounted for another 15 percent of the total value of potato imports. Most of these imports come from European countries. Seed potatoes are the third most important category of potato imports, accounting for 10 percent of quantity and 7.4 percent of the import value. The major potato seed supplying countries include the Netherlands, Australia, Germany and the United Kingdom. On average, Indonesia imports about 1,600 tons/year of potato seed, representing only about 1.5 percent of the total annual seed requirement.

Scientist Interviews

The scientist-respondents expect that with the late blight resistant potatoes, yield would increase between 5-50 percent (Table 8). They also expect that the adoption of the technology would reduce pesticide cost per hectare by 40-80 percent and hired labor cost by 5-10 percent. While there could be no change in fertilizer cost, it is expected that the cost of seeds could increase by 5-20 percent.

Scientist-respondents indicated a probability of 30-80 percent chances of success in developing transgenic potatoes with a commercially acceptable level of effectiveness against the late blight. They also believe that it could take about 5-8 years to complete the development of late blight resistant potatoes and to meet the various regulatory requirements with total expenditure of Rp300-410 million (USD 32,258-44,086) per year.

Table 8. Summary of scientist-respondents interview responses

Particular	Responses
Yield gain (%)	
Minimum	5-10
Most likely	15-30
Maximum	30-50
Cost change (%)	
Hired labor	decrease 5-10
Pesticides	decrease 5-10
Fertilizer	no change
Seeds	increase 5-20
Development and regulatory costs (Rp'000,000)	
Research and development	750 -1,000
Regulatory costs	
Contained	25 - 50
Limited field trial	25 - 50
Multi-location field trial	200 - 300
Food safety assessment	200 - 250
Apply for commercialization	50 - 100
Total costs for 5 years	1,500 - 2,050
Total cost per year	300 - 410
Preferred variety characteristic	
Variety type	saved seeds/OP
Variety source	private/public
Variety use	fresh (Granola, Manohara and Amudra); processed (Atlantic)

Industry Expert Interviews

Industry expert-respondents reported that from their experience, the estimated average annual crop loss due to late blight in 2005 was about 10-30 percent and about 10-50 percent in the last 5 years. The preferred varieties for which they would like the transgenic technology to be used, in order of preference, are Granola and Atlantic. Industry expert-respondents also reported that farmers normally prefer to use seeds saved from previous harvests and seeds bought from other farmers.

No conclusive response was obtained with regard to the time needed to complete the development of late blight resistant potato technology and to meet the various regulatory requirements. The chances (percent) that the product will pass the regulatory requirements and be commercialized were perceived to be low (< 10 percent), since the general knowledge and experience concerning the development of transgenic crops are still lacking. If the new released varieties are an improved version of Granola and Atlantic, the perceived maximum percentage of crop area expected to be covered by the transgenic potatoes was quite high at 50-80 percent. It was estimated that the maximum area to be planted (80 percent of total potato area) will be reached in 5-10 years once the crop is commercially released. If the new released varieties are an improved version of Granola and Atlantic and the price of the seed is relatively affordable, an increase in potato area will be expected, especially in potato production growing area outer Java.

Economic Surplus Analysis

The analysis was based on a set of 18 scenarios for potato production in Indonesia. The scenarios were grouped holding the variables "cost reduction per hectare" and "yield increase per hectare" constant to compare the results and infer the implications of seed markup on the distribution of economic benefits. Three levels of the seed markup were compared within each group of scenarios.

Technological change brought by the introduction of LBR transgenic potatoes increases the total surplus as a consequence of lower costs and higher yield. In Table 9, Groups I, II and III simulate a pesticide cost reduction of USD705 per hectare, while Groups IV, V and VI simulate a pesticide cost reduction of USD441 per hectare. Comparing scenarios P4 and P13 isolates the effect of the pesticide cost reduction per hectare. For scenario P4, the increase in total surplus is USD203 million, while for scenario P13 the increase in total surplus is USD134.5 million.

Comparing scenarios P1, P4 and P7 isolate the effects of three different values of yield increase: 24, 32 and 40 percent, respectively. A 24 percent yield increase (the lowest value) increases total surplus by USD169.7 million; 32 percent gives USD202.7 million total surplus; and a 40 percent yield increase results in a USD236.4 million increase in total surplus. The net present value (NPV) of benefits and costs shown in the last column of Table 9 is calculated by discounting and summing over time the difference between the benefits of the transgenic potato and the costs of research and regulatory investment. Because the research and regulatory costs are so small compared to the benefits, the last column in Table 9 is only slightly smaller than the discounted benefits alone, which are shown in the "total surplus" column.

Summary and Conclusion

This study applied an *ex-ante* analytical framework to evaluate the welfare impact of adopting late blight resistant (LBR) transgenic potatoes in Indonesia for the years 2005-2019. The size and distribution of economic benefits were estimated using an economic surplus closed economy model.

Each of the scenarios simulated for the LBR transgenic potatoes increased total economic surplus as costs were relatively small. The worst scenario (P12) produced national benefits of USD29.6 million, while the best scenario (P7) gave national benefits of USD236.4 million. The extent of adoption of the LBR transgenic potatoes has a major influence on the magnitude of benefits, which depend as well on factors such as the seed premium farmers may be asked to pay. In all the scenarios analyzed, higher adoption rates, of course, lead to increased benefits, but at the same time, adoption rates are likely to be lower, the higher the price markup for the transgenic seed. For the seed grower/company, profits may increase with higher seed markups under certain conditions, but may decrease with lower adoption rates. There is, therefore, an economic trade-off between seed markup and adoption rates.

This study has concentrated on the pecuniary benefits and costs of transgenic LBR potato and did not address issues such as environmental externalities. In this case, lower pesticide use is projected, which should have positive impacts on the environment, while the risk of unintended effects, such as gene flow, reduced biodiversity and harm to non-target organisms are perceived to be minimal.

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Table 9. simulation results for changes in economic benefits (USD)

Group	Scenario	Pesticide cost reduction (USD/ha)	Yield increase (%)	Seed mark-up (USD/ha)	NPV of change in (USD)			NPV of total surplus minus R&D costs (USD)
					Total surplus	Consumer ssurplus	Producer surplus	
I	P1	705	24	0	169,720,868	113,147,245	56,573,622	169,557,931
	P2	705	24	147	116,757,709	77,838,473	38,919,236	116,594,772
	P3	705	24	294	71,084,059	47,389,373	23,694,686	70,921,122
II	P4	705	32	0	202,694,488	135,129,659	67,564,829	202,531,551
	P5	705	32	147	141,755,427	94,503,618	47,251,809	141,592,489
	P6	705	32	294	87,935,733	58,623,822	29,311,911	87,772,796
III	P7	705	40	0	236,367,266	157,578,177	78,789,088	236,204,328
	P8	705	40	147	167,162,507	111,441,672	55,720,836	166,999,570
	P9	705	40	294	104,983,050	69,988,700	34,994,350	104,820,113
IV	P10	441	24	0	109,097,857	72,731,904	36,365,952	108,934,920
	P11	441	24	147	65,906,486	43,937,657	21,968,829	65,743,549
	P12	441	24	294	29,643,895	19,762,5973	9,881,298	29,480,958
V	P13	441	32	0	134,515,989	89,677,326	44,838,663	134,353,052
	P14	441	32	147	83,051,521	55,367,681	27,683,840	82,888,584
	P15	441	32	294	38,322,682	25,548,455	12,774,227	38,159,745
VI	P16	441	40	0	106,160,147	70,773,432	35,386,716	105,997,210
	P17	441	40	147	49,864,594	33,243,063	16,621,531	49,701,657
	P18	441	40	294	47,042,509	31,361,672	15,680,836	46,879,571

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Chapter 8

Costs and Benefits of *Bt* Potato with Resistance to Potato Tuber Moth in Indonesia

W. Adiyoga and G.W. Norton

Introduction

Potato tuber moth (*Phthorimaea operculella*), or PTM, attacks potatoes primarily in storage, and crop losses can reach 45-90 percent if untreated (Setiawari et al., 1998). In the field, yield loss can exceed 30 percent (Setiawati and Tobing, 1996; Soeriaatmadja, 1998), and farmers are then forced to apply significant amounts of insecticides to manage the pest.

Recently, genetic engineering has enabled researchers at Michigan State University, in collaboration with scientists at the International Potato Center (CIP, Lima, Peru), to develop a potato with resistance to PTM through the insertion of a synthetic gene designed for potato expression of a toxin identical to a *Bacillus thuringiensis* (*Bt*) gene. This synthetic potato gene will be referred to as the *Bt* gene. Several developing country potato varieties have been transformed with the *Bt* gene to express resistance to the potato tuber moth. For Central Africa (Rwanda, Burundi, Uganda, Congo), PTM-resistant varieties include Mabondo, Sangema, Murca, and Cruza 148. For the Andean region (Peru, Bolivia, Ecuador), PTM resistance is now in Tomasa Condemayta, Costanera, Achirana INTA, María Tambeña, and Revolución. For Colombia, Parda Pastusa has been transformed. For Costa Rica, PTM-resistant Atzimba is available, and for both North Africa (Egypt, Tunisia, Morocco) and the Southern cone of South America (Argentina, Chile), Spunta and Desiree has been transformed with the *Bt* gene. However, due to various limitations, only one of these PTM-resistant varieties has been deployed to their potential target countries. *Bt* Spunta has been field tested in Egypt, Indonesia, and South Africa. In the latter, *Bt* Spunta is going through the pathway of regulatory approval for commercialization. The material is in holdback in Egypt whereas in Indonesia, the *Bt* potato is under regulatory review for testing.

Farmers ranked PTM as the most important storage pest of potato, and the second most important pest problem after late blight. Farmers are concerned that the pest may increase over time and require increased use of insecticides, with potential harm to themselves and to the environment.

Indonesia has not been immune from the worldwide debate around the risks and ethics of transgenic crops. However, this debate often lacks information on the potential economic and environmental benefits from transgenic crops. Opponents and proponents of agricultural biotechnology often base their beliefs on perceptions rather than careful study (Qaim, 1999). Therefore, estimating the benefits that can be expected from the adoption of PTM-resistant potatoes in Indonesia can add useful information to the debate. The present study simulates the size and distribution of the economic surplus (economic benefits to producers and consumers) generated by the introduction and adoption of PTM-resistant potato variety in Indonesia. The potential effects on exports are considered, as well as the changes in pesticide use.

Methodology and Data Used

Economic surplus analysis was used to project the economic impacts of PTM-resistant or *Bt* potato. This approach, as discussed in more detail in Chapter 2, is commonly used to assess the economic impacts of agricultural research (Alston et al., 1995). The appropriate form of the model to be used in the analysis depends on the nature of the market for the product, i.e., the extent to which the product is traded or the existence of policy distortions. With any economic surplus analysis, basic information on production, prices, potential yield increases (or savings in losses), cost changes, and technology adoption (and non-adoption) over time are considered. Research and development (R&D) costs are subtracted from benefits and net benefits are discounted over time to generate a rate of return or a net present value (NPV) of the realized or projected net benefits (income). In case the research or regulatory process is not yet completed, the probability of success is estimated.

Over 95 percent of the potatoes in Indonesia are consumed domestically, with a few exports to Singapore and Malaysia. Potato exports have declined over time due to rising domestic demand and increased competition in the regional market. The basic model assumes a closed economy, although one model was run as an open economy for comparison.

Data Sources and Assumptions

Both primary and secondary data were collected and used in the analysis. Primary data were collected through farm survey interviews of 33 farmers in West Java and North Sumatra, five scientists working on the subject, and seven extension workers. Secondary data were obtained from various sources, including the Indonesian Central Bureau of Statistics and the Indonesian Ministry of Agriculture.

Per-hectare budgets with and without the new technology were developed to obtain the percent cost changes required when calculating the per-unit cost reduction estimates needed for the economic surplus evaluation. The budgets include both pre- and post-harvest costs. It is assumed that the transgenic variety affects yield (by reducing storage losses) and pesticide, labor, and seed costs, changing their value with respect to the benchmark figures under the traditional technology. To account for the uncertainty of the final value of these variables, the analysis is conducted across a range of feasible values. Each combination of values produces a scenario for the impact of the transgenic variety. The following sections explain the creation of scenarios, including the data used and the values selected for specific variables.

Three critical variables expected to change with the new technology are the use of variable inputs, the seed markup (or seed premium) charged for the new variety, and the yield net of storage losses. The primary variable inputs to change are the post-harvest insecticide cost and associated labor. The change in seed cost is in principle a component of the change in variable inputs per hectare (by changing the price of one input), but it is considered separately from other inputs to specifically account for a range in possible markups. The seed markup is the difference between the seed prices of the transgenic variety and of the traditional varieties. The markup may result from some monopoly power (due to a single or limited number of sellers) in addition to increased seed production costs which include regulatory costs.

The change in yield net of storage losses provides a measure of the change in physical productivity of the new variety. Although the transgenic characteristic does not necessarily lead to higher yield, it does result in a greater effective yield once the losses are reduced for the portion of the crop that is stored. The values included in the analysis for each of these variables were obtained from the farmer and scientist[1] surveys.

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[1] The scientists surveyed were Dr. Marc Ghislain, International Potato Center (CIP) Biotechnology Advisor; Dr. Keith Fuglie, CIP Division Leader; Dr. Muhammad Herman, Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (ICABIOGRAD) plant pathologist; Dr. Eri Sofiari, (Indonesian Vegetable Research Institute (IVEGRI) breeder; and Dr. Iteu M. Hidayat, IVEGRI breeder. Other scientists consulted include Dr. Jurgen Kroschel and Dr. Fernando Ezeta of CIP.

Adoption rates were based on the opinions of extension workers as described below. Adoption rates of a new technology are likely to increase as the expected net benefit increases, reducing the risk associated with the technology (Mills, 1998). In 2003, the Granola variety covered about 90 percent of the total annual potato area in Indonesia. Therefore, to maximize the adoption of the transgenic potato technology, this study assumed that the *Bt* gene was inserted into the Granola variety.

The study evaluated the stream of benefits derived from the adoption of the new technology over a 15-year period. The first years of the period are devoted to completing the research and meeting regulatory requirements. The length of the pre-adoption period was set based on responses of scientists who are knowledgeable about *Bt* potato and the regulatory system in Indonesia for transgenic crops. Farmer adoption was assumed to begin once the new variety is released and seeds are bulked up and disseminated, taking a few years to reach the maximum. The maximum adoption rate and the length of time to reach it were estimated based on the opinions of extension workers and other experts, and on the fact that farmers replace their seed every four to five years. Farmer adoption was assumed to proceed at a linear rate up to the maximum and then remain at that rate during the remainder of the 15-year period.

The literature has few studies on the own-price elasticity of potato demand. Pasaribu (1989) estimated the own-price elasticity to fall between –0.6 and –0.8. Fuglie et al. (2002) reported that per capita consumption of fresh table potatoes is currently much higher than processed potatoes and is likely to show strong growth in the future. Demand for fresh table potatoes in Southeast Asia appears to be relatively inelastic, with an own-price elasticity of around –0.17 to –0.22. Meanwhile, an own-price elasticity of potatoes in Jakarta, Indonesia was estimated at –0.5 (Fuglie et al., 2002). Based on these information, the potato demand own-price elasticity was set at –0.5.

The literature does not provide precise information from which to infer a proper value for the supply elasticity of potatoes in Indonesia. Alston et al. (1995) suggest that long-run elasticities can be high since in the long-run most fixed factors become variable. They also state that for empirical work when data are scarce, the supply elasticity can be set at 1, as elasticities that are very small or very large can give biased results in certain cases. Following this approach, this study set the potato supply elasticity at 1.

Because the PTM potato technology has not been released and the research and regulatory success is uncertain, the probability of success as well as the research and regulatory costs were elicited from the scientist-respondents. Wholesale prices and production were obtained from secondary data sources.

Results and Discussion

Primary Data and Secondary Data

Pest Management Practices and Pesticide Costs

Based on the farmer survey, pesticide cost in potato production in Indonesia averaged at USD762.00 per hectare, or 21.6 percent of the average production cost of USD3,524 per hectare in the wet season, and USD865 per hectare, or 24.6 percent of the average production cost of USD3,523 per hectare in the dry season. This study focuses on the dry season, when PTM is the greatest problem and more insecticides than fungicides are applied. Insecticide costs for managing PTM represent approximately 59 percent of total pesticide costs according to the 2006 farmer survey in West Java and North Sumatra. From the farmers' and scientists' surveys, farmer-adopters of *Bt* potato may expect a cost reduction of USD129-258 per hectare, or a 25-50 percent reduction in insecticide costs.

Farmers in West Java and North Sumatra rely heavily on chemical pesticides for managing insects and diseases (Table 1), with most farmers spraying on a schedule that they developed independent of pest severity in a particular year.

Table 1. Potato insect and disease control methods in West Java and North Sumatra, Indonesia, 2006

Pest and disease control method and frequency of practice	West Java (n=18) (%)	North Sumatra (n=15) (%)
Using bio-pesticide:		
• Never	55.6	73.3
• 1-4 times per season	44.4	26.7
Using natural enemies:		
• Never	100.0	100.0
• Sometimes	-	-
Using traps:		
• Never	44.4	60.0
• Sometimes	55.6	40.0
o Trap crop	22.2	20.2
o Sex pheromone	22.2	6.7
o Yellow trap	11.2	13.3

Pest and disease control method and frequency of practice	West Java (n=18) (%)	North Sumatra (n=15) (%)
Mixing pesticides:		
• Never	-	-
• Sometimes	11.1	26.7
• Always/very often	88.9	73.3
Number of pesticides mixed:		
• Two	33.3	60.0
• Three	55.6	26.7
• More than three	11.1	13.3
Frequency of spraying:		
• Twice a week	66.7	80.0
• Depends on the incidence	33.3	20.0
First and last spraying:		
• First spraying (days after planting)	16	13
• Last spraying (days before harvesting)	15	11

Potato farmers in West Java and North Sumatra also cited certain management practices as helpful in reducing PTM infestation (Table 2). For example, although they mainly use insecticides to control PTM both in the field and in storage, potato farmers in Indonesia carry out very careful tuber selection before moving them into storage.

Table 2. Management practices cited by farmers as helpful in reducing the infestation of potato tuber moth, 2006

Management practices	West Java		North Sumatra	
	No.	%	No.	%
Field practices				
• Fumigate soil before planting	2	11.1	0	0.0
• Apply insecticide in field	17	94.4	15	100.0
• Frequent irrigation	13	72.2	11	73.3
• Irrigate right up to harvest	15	83.3	8	53.3
• Timely harvest	12	66.7	8	53.3
• Harvest only in cool weather	0	0.0	6	40.0
• Harvest while the tops are still green	0	0.0	0	0.0
• Apply insecticide right before and/or after harvest	8	44.4	10	66.7

Management practices	West Java		North Sumatra	
	No.	%	No.	%
Post-harvest (storage) practices				
• Careful selection before moving tubers into storage	18	100.0	15	100.0
• Rapid handling between harvest and storage	14	77.8	10	66.7
• Apply insecticide in storage	18	100	12	80.0
• Good cover over stored potatoes	14	77.8	10	66.7
• Harvest only when plants are completely mature	1	5.6	4	26.7
No practice is actually necessary to reduce the infestation of potato tuber moth				
• Strongly disagree	8	44.4	5	33.3
• Disagree	10	55.6	8	53.3
• Indifferent	0	0.0	2	13.4
• Agree	0	0.0	0	0.0
• Strongly agree	0	0.0	0	0.0
No practice is actually effective to reduce the infestation of potato tuber moth				
• Strongly disagree	4	22.2	8	53.3
• Disagree	14	77.8	6	40.0
• Indifferent	0	0.0	1	6.7
• Agree	0	0.0	0	0.0
• Strongly agree	0	0.0	0	0.0

Seed Premium

One of the most important constraints in Indonesia's potato production is the availability of good quality seed at an affordable price. The average total seed cost is USD 1,022 per hectare, 29 percent of the total production cost. The percent seed premium for *Bt* potato markup is uncertain, but if *Bt* potato is developed and owned by the public sector, it is likely to be licensed to private partners with relatively small markup. CIP intends to initially license the *Bt* potato to an Indonesian private partner who will adhere to an agreed plan for release and reproduction. After a specified time period yet to be determined, the technology will be released to the public domain. The technology will not be owned by one particular partner. Based on this information and markups observed elsewhere, the seed markup is set in this study at 0 and at 10 percent (USD102) for the analyses.

Yield Increase

Indonesia's annual national potato yield during 1995-2004 averaged around 16 t/ha, a figure quite close to the world yield average. In some provinces, yields exceeded the national average. For example, West Java, which accounts for 39 percent of national production, posted an average yield of 19.8 t/ha in 2004 (see Appendix Table A-3).

Actual crop losses due to PTM from 2002 to 2005 were estimated by farmer-respondents to be at 0-30 percent in West Java and North Sumatra, even after application of insecticides. In response, scientist-respondents indicated that *Bt* potato may completely eliminate storage losses due to PTM. For this study, yield increase with the *Bt* potato was allowed to range at 0-10 percent.

The information above was used to generate 12 scenarios for the analysis (Table 3). The scenarios can also be depicted as a decision tree with the decision levels corresponding to the variables whose values were made to change in the simulations. The first level on the tree (1st column) is the decrease in pesticide cost due to the use of new technology. The second level (2nd column) includes the various levels of yield increase per hectare (in percentages). The third level (3rd column) is the amount of seed markup.

Table 3. Construction of different cost and yield scenarios for *Bt* potato

Pesticide cost reduction (USD/ha)	Yield increase (%)	Seed markup (USD/ha)	Scenario
258.30	0	0	P1
		102.2	P2
	5	0	P3
		102.2	P4
	10	0	P5
		102.2	P6
129.15	0	0	P7
		102.2	P8
	5	0	P9
		102.2	P10
	10	0	P11
		102.2	P12

Harvested Area, Production, and Yield

Potato is grown throughout the highlands of Indonesia. During the period 1995-2004, Indonesia's potato area ranged from a low of 50,189 ha in 1997 to a high of 73,069 ha in 2000. During the same period, production ranged from a low of 813,368 t in 1997 to a high of 1,321,117 t in 2002 (see Appendix Table A-1). In 2003, the three most important potato producing provinces accounted for about 73 percent of national production – West Java, 37.1 percent; North Sumatra, 23.3 percent; and Central Java, 12.5 percent. Six other provinces, namely: Aceh, West Sumatra, Jambi, East Java, South Sulawesi and North Sulawesi are also considered important potato producing areas. In 2003, these nine provinces accounted for nearly all of Indonesia's national potato production (see Appendix Table A-2). The base quantity used was calculated using average harvested area and average yield for the period 2000 to 2004, which were at 64,585 ha and 16.2 t/ha respectively. Thus, the base quantity was set at 1,047,568.7 tons.

Per Hectare Budgets

Average costs and returns for potato production in the 2005 dry season and in the 2006 wet season for West Java and North Sumatra are presented in Appendix Table A-3 to Table A-6. Purchased inputs account for 67-74 percent (USD2,248 - 2,561 per ha) of total costs. Total labor requirements average at 23 percent of total cost (USD630 per ha). Based on an average yield of 25.2 t/ha (wet season) and 20.9 t/ha (dry season), average farm income was estimated at USD2,695 and USD1,853, respectively. The budget varies considerably with respect to specific cost items due mostly to different definitions/categories used to report specific cost items, reporting years, and the way each budget values family labor.

Varieties

All income groups in Indonesia consume potatoes and consumers prefer a soft texture, slightly sweet taste, and yellowish flesh color (Ameriana et al., 1998). Ninety-one percent of the potatoes planted are the Granola variety, with farmers replacing their seed stock with new seed every four to five seasons. About 6 percent of the potato area is sown to processing varieties, such as Columbus, Atlantic and Panda. The rest is planted to an assortment of varieties, including a popular selection in East Java known as Ritex (see Appendix Table A-7). Table 4 presents the dominant potato varieties grown and the different sources of potato seed in West Java and North Sumatra.

Table 4. Variety used and potato seed sources in West Java and North Sumatra, 2006

Variety grown and seed source	West Java (n=18)		North Sumatra (n=15)	
	Wet season	Dry season	Wet season	Dry season
Variety grown (%)				
• Granola	88.9	94.4	100.0	100.0
• Atlantic	11.1	5.6	-	-
Seed sources (%)				
• Own seed	55.6	44.4	73.4	80.0
• Seed grower	16.6	27.8	13.3	13.3
• Seed trader	5.6	16.6	13.3	6.7
• Formal seed system	11.1	5.6	-	-
• Potato chip processing company	11.1	5.6	-	-

Farm Size

Small farms dominate highland vegetable production in Indonesia. Potato farms average at about 1 ha, with few farms over 2 ha. The land market is well developed and cash rent predominates. About 60 percent of the potato area in West Java is rented, more than double the proportion in other provinces. In the latter locations, about 6 percent of the sample potato growers were landless households who rent land to grow potatoes, 50 percent use their own land, and the rest uses both owned and rented land. The average amount of cropland owned per household was 1.6 ha with an additional net rental area (area rented minus area rented out) of 0.34 ha.

Marketing Channels

Commercial potato farmers typically harvest their crop and sell it to middlemen who visit their farms. Some farmers also directly market their crop to vegetable sellers in nearby public markets or have contracts to supply supermarkets (for table potato) or a food processing company (for processing potato). In contrast, middlemen generally sell to large wholesale markets, located in major urban areas. Indonesia consumes most of its potato production domestically, importing/exporting only small quantities of the produce (Adiyoga et al., 1999; Adiyoga et al., 2000).

Potato Trade

In most years, North Sumatra accounts for more than 90 percent of Indonesia's potato exports. Nearly all of Indonesia's potato exports are destined for either Malaysia (about 70 percent of total potato exports) or Singapore (30 percent of total exports). Between 1997 and 2002, exports were relatively stable averaging 30,598 tons/year, or about 3.2 percent of domestic production (see Appendix Table A-8).

Most potato imports are in the form of processed products, with nearly three-quarters of the value being frozen French fries (see Appendix Table A-9). Most of these imports originate from North America. Other processed potato products (such as starch and flakes) account for another 15 percent of the value of potato imports, which come from European countries. Seed potatoes are the third most important category of imports, accounting for 10 percent of quantity and 7.4 percent of the value of total potato imports. The major potato seed supplying countries include the Netherlands, Australia, Germany and the UK. On average, potato seed imports are about 1,600 tons/year, representing only about 1.5 percent of the total annual seed requirement.

Farm-Gate and Wholesale Prices

Appendix Table A-10 presents the seasonal pattern of monthly farm-gate and wholesale prices for potato in West Java during 1997-2003. Farm-gate prices of potato in February averaged 18.0 percent below the yearly average price (USD0.28 per kg), and those in November averaged 21.0 percent above the yearly average price. The same pattern occurred at the wholesale price level. Wholesale prices for potatoes for the period 2003-2005 averaged USD0.39 per kg. The base price for the economic model was set initially at USD394 per ton.

Scientist Interviews

International and local Indonesian scientists were interviewed about issues such as the most likely reduction in storage losses and percentage changes in production costs if *Bt* potato is adopted. They were also asked about the chances of research success, time and costs involved in meeting regulatory requirements, and other related issues.

Scientists estimate that the adoption of PTM-resistant potato may most likely reduce storage loss by at least 30 percent and at most 95 percent. The lowest possible storage loss with such adoption was thought to be about 20 percent, and the highest was 100 percent. The *Bt* gene should be quite effective at providing resistance to PTM in Indonesia. Insect pressure is not high, given the short duration of most potato storage in Indonesia.

The scientists also estimated that, among the inputs used for potato production, the share of seed cost in total production cost may increase by 5-10 percent, that of pesticide costs may decrease by 10-40 percent and that of hired labor may also decrease by 5-10 percent, with the adoption of PTM-resistant potato (Table 5). In addition, the scientists estimated that there is a 25-100 percent probability (percent chance) of biotech research developing a solution with a commercially acceptable level of effectiveness against potato tuber moth. *Bt* potato technology has been successfully developed in other countries with PTM species similar to that found in Indonesia. The efficacy of the *cry1Ab* gene against lepidopteran species and in particular the tuber moth present in Indonesia has been scientifically established in the laboratory, greenhouse, field, and storage conditions with 100 percent resistance in all cases (Ghislain et al., 2003). However, the experts added that it may take five years to obtain a *Bt* potato variety if one of 10 currently being tested proves suitable (Table 6). If a new *Bt* variety is needed, the time schedule would likely shift by three years. Given the absence of commercial GMO foods produced in Indonesia, these estimates are highly uncertain. Unless the benefits of the technology are shown to be large, government regulators may be slow to approve it given the resistance from environmental or civil society groups.

Table 5. Estimated percent change in input cost share in total potato production cost if the PTM-resistant potato is adopted, 2006

Variable cost	Current share (%) in total production cost	Most likely change in cost	
		Direction	Percent
Hired labor	23.3	Decrease	5–10
Fertilizer	16.2	No change	
Pesticides	23.1	Decrease	10-40
Field	21.4		
Storage	1.7		
Seeds	28.7	Increase	5-10
Marketing	5.0	No change	

Table 6 also shows in the last column the expected (estimated) costs involved in developing the *Bt* potato technology and meeting the regulatory requirements in Indonesia. The numbers assume that regulators will accept most of the risk assessment data already available for *Bt* potato; the total costs could double if this assumption is wrong. Estimates of field trial costs are based on CIP's previous experience with non-GMO variety testing. Estimated costs

Table 6. Time and investments needed to complete the PTM-resistant potato technology and to meet the regulatory requirements

	Year										Estimated costs (USD '000)
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Technology development	X										20 - 50
Regulatory		X	X	X	X	X	X	X			
Contained		X									10 – 20
Limited field trial			X								40 – 60
Multi-location field trial				X	X						50 – 120
Food safety assessment					X						50 – 100
Apply for commercialization					X	X	X	X			80 – 200*
Communication	X	X	X	X	X	X	X	X	X	X	
Estimated total costs for five years											250 - 550
Estimated total costs per year											50 - 110

* Includes communication

of applying for commercialization are highly uncertain. Costs of educating the public and civil society groups about *Bt* potato are included as part of the application for commercialization process.

The scientist-respondents were also asked on the type of variety that should be developed with PTM technology. The scientist-respondents opined that both hybrid and open-pollinated varieties (OPV) should be developed. Since Indonesia is not a center of diversity for this crop, gene flow should not be a concern unless the regulatory body decides otherwise. Hence, farmers could be allowed to save seeds from OPVs. The scientist-respondents noted that farmers prefer to source their planting materials from both the public and the private seed producers. However, the license for use of the *Bt* technology is only for public domain varieties. Since farmers derive income from both processing and fresh/table type potato varieties, both types should be considered. Lastly, in terms of target market, the scientist-respondents expressed preference to develop PTM varieties for the domestic market first to simplify the first phase of commercialization, with possibilities of developing varieties for export in the future.

In terms of ownership and distribution of the seed technology in Indonesia, CIP intends to license the *Bt* potato to an Indonesian private partner who will adhere and has the demonstrated capability to implement a mutually agreed work plan. After a period yet to be determined, the technology will be fully released to the public domain. Alternative technology transfer scenarios may be discussed, but the *Bt* varieties will not be owned by one particular partner as stipulated in CIP-Plant Genetic System (technology provider) licensing agreement. The Indonesian public partner will have to distribute the planting material either directly or through a local private sector partner.

As for potential environmental effects, the scientist-respondents expressed no or very minimal concern for fears relating to gene flow and reduced biodiversity. They also believe that *Bt* potato will not harm beneficial insects, particularly herbivores. However, the scientist-respondents expressed that insect resistance management will be crucial to avoid potato tuber moth developing resistance against the *Bt* toxin. Nevertheless, the last two points can be addressed by multidisciplinary research during the various contained, limited, and multi-location field trials, in parallel with the conventional agronomic performance and trait stability trials. Most of the scientist-respondents indicated that farmers would not be able to differentiate a *Bt* potato variety from the same non-GM variety. This means that the *Bt* potato will be substantially equivalent in agronomic and compositional traits to its non-*Bt* counterpart.

Most potato seed in Indonesia is not formally certified, and most farmers renew their seed once every three to five seasons by purchasing (non-certified) seed through the "informal" seed market. Some farmers specialize in purchasing imported seed (which has been certified by a foreign seed authority), multiplying it for a few seasons and then selling it as improved seed through the informal market. Such seed from reputable seed growers can command a price premium in the informal seed market.

Certified *Bt* potato seed would command a price premium that would reflect its general disease-free status as well as its resistance to PTM. However, given that PTM does not appear to be a major economic problem in Indonesia, it is suspected that farmers would not be willing to pay more than a 5-10 percent premium over the normal cost of certified seed for the PTM resistance itself.

Extension Expert Interviews

Seven extension experts were interviewed to elicit their opinions on crop losses due to PTM and their projections on the rate of adoption of *Bt* potato. A summary of their responses is provided below, with survey questions provided in Appendix 2.

In general, potato farmers in West Java and Northern Sumatra prefer the Granola and Atlantic varieties, in that order. Farmers source their potato seed from their own harvest and/or from seed purchased from other farmers. The extension experts estimated that potato farmers lost about 10-60 percent of their crops to PTM in the last five years. In 2005 alone, they may have lost 10-35 percent of seed material and 3-10 percent of the produce for table consumption.

While some expected no change in the area planted to potatoes in Indonesia, some of the extension experts projected that the next 10 years in Indonesia will see a 10-20 percent decrease in the same.

The extension experts also perceive that a transgenic (*Bt*) potato with resistance to tuber moth has a 50-80 percent chance of passing the regulatory requirements and being commercialized in Indonesia. A maximum of 70-90 percent of the potato area in the country may be planted to *Bt* potato once available, although it may take two to five years after commercial release before this maximum adoption rate is reached.

Table 7 presents the potential adoption paths for *Bt* potato in Indonesia. Adoption rates depend on the technology's profitability, which in turn is determined by the proportionate change in input cost per ton of produce. Per unit cost changes depend on the changes in pesticide costs per hectare, the seed markup, and the expected increase in yield per hectare in each scenario. The same pattern was assumed in this study. The proportionate input cost changes per ton of produce for each scenario are divided into the different levels of maximum adoption rate (20, 40, or 60 percent) (Table 8).

Table 7. Potential adoption paths for *Bt* potatoes (percent adoption per year)

Year	Maximum expected adoption rate		
	20%	**40%**	**60%**
2007	0	0	0
2008	0	0	0
2009	0	0	0
2010	0	0	0
2011	0	0	0
2012	0	0	0
2013	0	0	0
2014	5.9	11.7	17.6
2015	10.0	20.0	30.0
2016	14.1	28.2	42.3
2017	17.1	34.2	51.3
2018	18.7	37.4	56.1
2019	19.4	38.8	58.3
2020	19.8	39.6	59.4
2021	20.0	40.0	60.0

Table 8. Proportionate input cost change per ton and maximum adoption rates for transgenic potatoes

Scenario	Maximum adoption rate (%)	Cost reduction (USD)	Seed markup (USD)	Yield increase (%)	Proportionate input cost change per ha (USD)	Proportionate input cost change per ton (USD)
P1	20	258.3	0	0	0.07	0.07
P2	20	258.3	102.2	0	0.04	0.04
P3	40	258.3	0	5	0.15	0.14
P4	40	258.3	102.2	5	0.12	0.11
P5	60	258.3	0	10	0.23	0.21
P6	60	258.3	102.2	10	0.20	0.18

Scenario	Maximum adoption rate (%)	Cost reduction (USD)	Seed markup (USD)	Yield increase (%)	Proportionate input cost change per ha (USD)	Proportionate input cost change per ton (USD)
P7	20	154.8	0	0	0.04	0.04
P8	20	154.8	102.2	0	0.01	0.01
P9	40	154.8	0	5	0.11	0.11
P10	40	154.8	102.2	5	0.08	0.08
P11	60	154.8	0	10	0.19	0.17
P12	60	154.8	102.2	10	0.16	0.15

Summary of Basic Assumptions Used in the Economic Model

Based on the primary information gathered from the farmer, scientist and extension worker surveys, as well as the secondary information, the set of basic assumptions applied in the economic model are listed in Table 9.

Table 9. Parameter values for the computation of economic surplus changes

Parameter	Description and value
Year	Annual benefits are projected for 15 years after research commences, 2007-2021 (t = 1,2,…,15)
Supply elasticity	The supply elasticity, e, is set at 1.0
Demand elasticity	The demand elasticity, n, is set at –0.5
Proportionate yield change	Percentage yield increases are assumed to be 0%, 5% and 10%
Proportionate change in input cost per hectare	The pesticide cost reduction is set at USD258 (50%) and USD129 (25%). The seed premium is set for 0% (USD0) and 10% (USD102) per hectare. Combining these with the yield changes, the proportionate changes in per unit cost vary from USD0.00765 to USD0.20725 per ton.
Probability of research success and regulatory approval	The probability of research and regulatory success is assumed to be 50%.
Adoption rate	For the purpose of simulation the assigned maximum adoption rates are 20%, 40%, and 60%. It is assumed that research, regulatory approval, and bulking up of seeds take seven years and adoption starts from year eight onwards.
Price	Wholesale prices are set at USD394 per ton.

Parameter	Description and value
Production quantity	The pre-research production quantity is set at 1,047,669 tons.
Research cost	The estimated annual research and regulatory cost for *Bt* potatoes is USD80,000 per year.

Economic Model Results

Combining the variables discussed above, a set of 12 scenarios were produced for analyzing *Bt* potatoes and the range of its projected economic benefits. Table 10 shows the simulation results for these scenarios. The first column indicates the specific scenarios, which are grouped first by level of pesticide cost reduction (column 2). The third and fourth columns indicate three levels of yield increase per hectare and two levels of seed markup, respectively. The fifth column presents the Net Present Value (NPV) over the 15 years of the change in total economic surplus for each scenario. Because most of the potatoes produced in Indonesia are consumed domestically, two thirds of those benefits accrue to potato consumers and one third accrues to producers. The last column represents the NPV of the change in total economic surplus after subtracting research and regulatory costs. The NPV is the present worth of the net income stream generated by the research and regulatory investment over time. It is calculated by discounting the difference of the incremental benefits and costs of the technology over the 15-year period.

A dozen scenarios is presented in this study because of the uncertain nature of several parameters, which in various combinations can create a sizable range of potential benefits (USD1 million to USD133 million). Intermediate values of the parameters result in benefits over the time period in the USD37-47 million range, a sizable return on a very modest investment. The corresponding internal rate of return (IRR) on the public investment varies from 20 to 116 percent. The rates of return for the intermediate values of the parameters vary from 84 to 89 percent. Even under the most conservative assumptions, the net economic benefits are significant, in part because the research and regulatory costs are so small in relation to benefits.

The export market for Indonesian potatoes is small (3-4 percent of production). Therefore, even if the export market reacts negatively to the introduction of transgenic potatoes, it would have minimal impact on the level of the technology's benefits. However, if the export market grows as a result of Indonesia being able to guarantee potatoes with less pesticide residue, the benefits would of course increase for the producers.

Table 10. Potato simulation results for changes in economic benefits (USD)

Scenario	Pesticide cost reduction (USD/ha)	Yield increase (%)	Seed markup (USD/ha)	Net present value of change in total surplus (USD)	Net present value of total surplus less R&D costs (USD)	Internal rate of return (IRR) (%)
P1	258	0	0	10,518,380	10,172,021	56
P2	258	0	102.2	6,354,069	6,007,711	47
P3	258	5	0	55,727,892	55,381,534	93
P4	258	5	102.2	47,733,151	47,386,793	89
P5	258	10	0	133,794,733	133,448,374	116
P6	258	10	102.2	122,172,902	121,826,544	114
P7	129	0	0	5,688,322	5,341,964	45
P8	129	0	102.2	1,096,450	750,092	20
P9	129	5	0	45,626,961	45,280,603	88
P10	129	5	102.2	37,724,649	37,378,291	84
P11	129	10	0	119,113,443	118,767,085	113
P12	129	10	102.2	107,527,364	107,181,006	110

Summary and Conclusion

This study used an *ex-ante* analytical framework to evaluate the welfare impact of developing, releasing, and adopting *Bt* potatoes in Indonesia over the years 2007-2021. The results indicate that the *Bt* technology in Indonesia's potato sector potentially would have a sizable impact on society's economic welfare. All the scenarios simulated for *Bt* potato yielded high economic benefits. The worst scenario produced national benefits of USD1.1 million, while the best scenario provided projected national benefits of USD133.8 million (across which IRR range at 20-116 percent). Potato farmers gain even with a lower output price because the *Bt* technology would increase the marketable yield and lower production costs.

The extent of adoption of the transgenic *Bt* potatoes will influence the magnitude of the benefits and will depend in part on the seed premium farmers must pay. For the seed producer/company, profits may increase with higher seed markups under certain conditions, but may also decrease with lower adoption rates. Hence, as with any other new seed-based technology, there is an economic trade-off between the seed markup and the adoption rates.

This study has concentrated on the pecuniary benefits and costs of transgenic *Bt* potato and did not address possible environmental externalities. Nevertheless, it should be mentioned that a lower use of insecticides would have positive impacts on the environment, while the risk of unintended effects, such as gene flow, reduced biodiversity and harm to non-target organisms are perceived to be minimal.

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Appendix 1.

Table A-1. Potato production in Indonesia, 1995-2004

Year	Harvested (ha)	Production (t)	Yield (t/ha)
1995	62,388	1,035,259	16.6
1996	69,946	1,109,560	15.9
1997	50,189	813,368	16.2
1998	65,047	998,032	15.4
1999	62,776	924,058	14.7
2000	73,068	977,349	13.4
2001	55,971	831,140	14.9
2002	62,545	1,321,117	21.1
2003	65,923	1,009,979	15.3
2004	65,420	1,072,040	16.4

Source: Direktorat Jenderal Tanaman Pangan dan Hortikultura

Table A-2. Potato production in Indonesia, 1995-2004

Province		1999	2000	2001	2002	2003	2004
Aceh	Area (ha)	561	336	425	93	1,529	1,659
	Prod (t)	5,960	4,599	6,130	2,170	28,286	30,333
	Yield (t/ha)	13.69	14.40	23.00	18.50	18.28	10.62
North Sumatra	Area (ha)	13,325	15,275	12,093	16,910	14,301	9,681
	Prod (t)	192,574	215,981	207,918	317,962	235,424	153,537
	Yield (t/ha)	14.45	14.14	17.20	18.80	16.46	15.86
West Sumatra	Area (ha)	1,475	1,404	972	1,156	1,094	1,719
	Prod (t)	20,479	21,213	10,822	26,578	13,889	30,489
	Yield (t/ha)	13.80	15.11	11.10	23.00	12.70	17.74
Jambi	Area (ha)	1,874	2,630	2,127	1,527	3,197	3,139
	Prod (t)	34,341	41,754	36,959	24,676	60,896	58,717
	Yield (t/ha)	18.33	15.87	17.40	16.20	19.05	18.71

Province		**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
West Java	Area (ha)	22,998	27,778	23,045	22,822	20,146	21,092
	Prod (t)	410,483	462,800	385,618	610,626	375,167	418,230
	Yield (t/ha)	17.85	16.66	16.70	26.80	18.62	19.83
Central Java	Area (ha)	11,576	7,176	5,932	7,395	8,182	9,680
	Prod (t)	148,806	86,424	76,926	128,305	126,222	161,213
	Yield (t/ha)	12.86	12.04	13.00	17.40	15.43	16.65
East Java	Area (ha)	6,796	7,551	6,331	7,214	8,902	7,263
	Prod (t)	71,548	81,372	72,926	124,196	97,308	105,254
	Yield (t/ha)	10.53	10.78	11.40	17.20	10.93	14.49
South Sulawesi	Area (ha)	1,739	3,182	2,303	1,268	1,208	1,208
	Prod (t)	20,381	32,720	10,351	22,726	19,169	12,205
	Yield (t/ha)	11.72	10.28	14.50	17.90	15.87	10.10
North Sulawesi	Area (ha)	346	5,795	1,579	2,278	6,234	8,446
	Prod (t)	2,698	15,974	12,362	48,338	44,293	86,487
	Yield (t/ha)	7.80	2.76	7.80	21.20	7.11	10.24
Total	Area (ha)	60,690	71,127	54,807	60,570	64,793	63,887
	Prod (t)	907,270	921,083	820,012	1,305,577	1,000,654	1,056,465
	Yield (t/ha)	13.12	12.37	12.61	20.17	15.44	16.54
Other provinces	Area (ha)	2,086	1,941	1,164	1,975	1,130	1,533
	Prod (t)	16,788	56,266	11,128	15,540	9,325	15,575
	Yield (t/ha)	7.30	9.34	11.23	7.87	8.25	10.16
Indonesia	Area (ha)	62,776	73,068	55,971	62,545	65,923	65,420
	Prod (t)	924,058	977,349	831,140	1,321,117	1,009,979	1,072,040
	Yield (t/ha)	14.72	13.38	14.80	14.90	15.32	16.39

Source: Direktorat Jenderal Tanaman Pangan dan Hortikultura

Table A-3. Costs and returns (per ha) of potato production, Pangalengan, West Java, Dry Season, 2005

Particular	Pangalengan, Jawa Barat, 2005			
	Quantity	Value (Rp)	Value (USD)*	% from total expenses
INPUTS				
Labor				
• Preparing land (work days)				5.9
• Male	148	1,480,000	159.1	
• Female	50	400,000	43.0	
• Planting (work days)				1.1
• Male	18	180,000	19.4	
• Female	22	176,000	18.9	
• Applying inputs and others (work days)				9.6
• Male	259	2,590,000	278.5	
• Female	61	488,000	52.4	
• Harvesting and postharvesting (work days)				4.1
• Male	99	990,000	106.5	
• Female	41	328,000	35.3	
Sub total		6,632,000	713.1	20.7
Material Inputs				
Seed (kg)	1,500	9,105,000	979.0	28.4
Synthetic fertilizer (kg)	1,600	2,485,500	267.3	7.8
Organic fertilizer (kg)	16,000	3,224,000	346.7	10.1
Foliar fertilizer (gr or cc)		224,750	24.2	0.7
Lime (kg)		-	-	-
Fungicide		3,410,400	366.7	10.5
Insecticide		4,795,200	515.6	15.0
Other inputs		568,500	61.1	1.8
Sub total		23,813,350	2,560.6	74.3
Other Costs				
Land rent (Rp./ha)		1,500,000	161.3	4.7
Others		117,500	12.6	0.3
Sub total		1,617,500	173.9	5.0

Particular	Pangalengan, Jawa Barat, 2005			
	Quantity	Value (Rp)	Value (USD)*	% from total expenses
Total Expenses		32,062,850	3,447.6	100.0
OUTPUT				
Production (kg)	21,860			
Price (Rp/kg)	2,225.2			
Total Revenue		48,642,872	5,230.4	
FARMER'S INCOME		16,580,022	1,782.8	
INCOME OVER EXPENSES		51.7%		

Source: 2006 Farmer survey
*USD1.00 = Rp9,300

Table A-4. Costs and returns (per ha) of potato production, Pangalengan, West Java, Wet Season, 2006

Particular	Pangalengan, Jawa Barat, 2006			
	Quantity	Value (Rp)	Value (USD)*	% from total expenses
INPUTS				
Labor				
• Preparing land (work days)				5.0
• Male	135	1,350,000	145.2	
• Female	48	384,000	41.3	
• Planting (work days)				1.0
• Male	17	170,000	18.3	
• Female	24	192,000	20.6	
• Applying inputs and others (work days)				13.2
• Male	389	3,890,000	418.3	
• Female	82	656,000	70.5	
• Harvesting and postharvesting (work days)				4.9
• Male	124	1,240,000	133.3	
• Female	54	432,000	46.5	
Sub total		8,314,000	894.0	24.1

Particular	Pangalengan, Jawa Barat, 2006			
	Quantity	**Value (Rp)**	**Value (USD)***	**% from total expenses**
Material Inputs				
Seed (kg)	1,695	10,122,540	1,088.4	29.3
Synthetic fertilizer (kg)	1,215	1,887,500	203.0	5.4
Organic fertilizer (kg)	18,450	3,480,000	374.2	10.1
Foliar fertilizer (gr or cc)		261,850	28.2	0.8
Lime (kg)		127,985	13.7	0.4
Fungicide		5,729,600	616.1	16.6
Insecticide		2,105,250	226.3	6.1
Other inputs		939,425	101.0	2.7
Sub total		24,654,150	2,650.9	71.4
Other Costs				
Land rent (Rp./ha)		1,500,000	161.3	4.4
Others		45,000	4.8	0.1
Sub total		1,545,000	166.1	4.5
Total Expenses		34,513,150	3,711.1	100.0
OUTPUT				
Production (kg)	28, 462			
Price (Rp/kg)	2,193.64			
Total Revenue		62,435,382	6,713.5	
FARMER'S INCOME		27,922,232	3,003.6	
INCOME OVER EXPENSES		80.9%		

Source: 2006 Farmer survey

*USD1.00 = Rp9,300

Table A-5. Costs and returns (per ha) of potato production, Berastagi, North Sumatra, Dry Season, 2005

Particular	Pangalengan, Jawa Barat, 2006			
	Quantity	Value (Rp)	Value (USD)*	% from total expenses
INPUTS				
Labor				
• Preparing land (work days)				4.8
• Male	176	1,320,000	141.9	
• Female	38	285,000	30.6	
• Planting (work days)				1.4
• Male	24	228,000	24.5	
• Female	28	210,000	22.6	
• Applying inputs and others (work days)				12.1
• Male	364	3,458,000	371.8	
• Female	80	600,000	64.5	
• Harvesting and postharvesting (work days)				4.7
• Male	124	1,178,000	126.7	
• Female	56	420,000	45.2	
Sub total		7,699,000	827.8	23.0
Material Inputs				
Seed (kg)	1,625	9,912,500	1065.9	29.6
Synthetic fertilizer (kg)	1,450	2,247,500	241.7	6.7
Organic fertilizer (kg)	15,800	2,765,500	297.4	8.3
Foliar fertilizer (gr or cc)		180,750	19.4	0.5
Lime (kg)		-	-	-
Fungicide	7890200	3,077,175	330.9	9.2
Insecticide		4,813,050	517.5	14.4
Other inputs		630,250	67.7	1.9
Sub total		23,626,725	2,540.5	70.6
Other Costs				
Land rent (Rp./ha)		1,850,000	198.9	5.5
Others		285,500	30.7	0.9
Sub total		2,135,500	229.6	6.4

Particular	Pangalengan, Jawa Barat, 2006			
	Quantity	Value (Rp)	Value (USD)*	% from total expenses
Total Expenses		33,461,225	3,597.9	100.0
OUTPUT				
Production (kg)	20,054			
Price (Rp/kg)	2,560.5			
Total Revenue		51,348,267	5,521.3	
FARMER'S INCOME		17,887,042	1,923.3	
INCOME OVER EXPENSES		53.5%		

Source: 2006 Farmer survey
*USD1.00 = Rp9,300

Table A-6. Costs and returns (per ha) of potato production, Berastagi, North Sumatra, Wet Season, 2006

Particular	Pangalengan, Jawa Barat, 2006			
	Quantity	Value (Rp)	Value (USD)*	% from total expenses
INPUTS				
Labor				
• Preparing land (work days)				6.4
• Male	164	1,558,000	167.5	
• Female	58	435,000	46.8	
• Planting (work days)				1.2
• Male	28	266,000	28.6	
• Female	16	120,000	12.9	
• Applying inputs and others (work days)				12.7
• Male	356	3,382,000	363.7	
• Female	74	555,000	59.7	
• Harvesting and postharvesting (work days)				5.1
• Male	138	1,311,000	140.9	
• Female	36	270,000	29.0	
Sub total		7,897,000	849.1	25.4

Particular	**Pangalengan, Jawa Barat, 2006**			
	Quantity	**Value (Rp)**	**Value (USD)***	**% from total expenses**
Material Inputs				
Seed (kg)	1,381	8,457,244	909.4	27.3
Synthetic fertilizer (kg)	1,666	2,582,300	277.7	8.3
Organic fertilizer (kg)	16,550	2,482,500	266.9	8.0
Foliar fertilizer (gr or cc)		127,500	13.7	0.4
Lime (kg)		225,745	24.3	0.7
Fungicide		4,386,565	471.7	14.1
Insecticide		1,952,400	209.9	6.3
Other inputs		689,750	74.2	2.2
Sub total		20,904,004	2,247.8	67.4
Other Costs				
Land rent (Rp./ha)		1,850,000	198.9	6.0
Others		375,000	40.3	1.2
Sub total		2,225,000	239.2	7.2
Total Expenses		31,026,004	3,336.1	100.0
OUTPUT				
Production (kg)	21,940			
Price (Rp/kg)	2,425.60			
Total Revenue		53,217,664	5,722.3	
FARMER’S INCOME		22,191,660	2,386.2	
INCOME OVER EXPENSES		71.5%		

Source: 2006 Farmer survey
*USD1.00 = Rp9,300

Table A-7. Potato farm area and varieties planted in 2000

Particular	**West Java**	**Central Java**	**East Java**	**North Sumatra**	**West Sumatra**	**Indonesia**
Average potato area harvested per farm (ha/year)	1.34	1.87	0.46	0.46	0.47	0.96

Particular	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia
Area planted to Granola (%)	87.1	97.8	76.6	95.2	100.0	91.4
Area planted to processing varieties (%)*	12.9	0.0	0.0	4.8	0.0	5.6
Area planted to other varieties (%)^	0.0	2.2	23.4	0.0	0.0	3.0

* These include Atlantic, Columbus, Hetra, and Panda.
^ Other varieties consist mainly of Ritex, a farmer-selected variety popular in East Java.
Source: Fuglie et al. (2004)

Table A-8. Potato production in Indonesia, 1995-2004

Year	Quantity ('000 t)	Value (USD million)	Price (USD/t)
1994	89.12	14.08	158
1995	103.05	18.22	177
1996	79.75	15.09	189
1997	36.76	8.43	229
1998	31.25	5.96	191
1999	33.26	6.72	202
2000	30.23	4.46	148
2001	31.34	4.59	146
2002	20.75	4.22	203

Source: Direktorat Jenderal Tanaman Pangan dan Hortikultura

Table A-9. Indonesian potato imports, 1994-2002

Year	Total ('000 t)	Table ('000 t)	Seed ('000 t)	Frozen ('000 t)	Others ('000 t)
1994	9.86	0.33	0.87	6.58	2.08
1995	13.40	0.31	0.78	9.72	2.59
1996	17.22	0.89	1.21	11.83	3.29
1997	27.63	2.04	0.90	23.06	1.63
1998	9.71	0.68	0.36	6.92	1.74
1999	24.14	3.18	6.12	6.48	8.36
2000	19.82	4.57	1.26	10.41	3.59
2001	8.16	2.68	1.14	-	-
2002	5.42	2.34	1.44	-	-

Source: Direktorat Jenderal Tanaman Pangan dan Hortikultura

Table A-10. Seasonal pattern of potato prices at the farm-gate level (Pangalengan, West Java) and at the wholesale level (Jakarta wholesale market), 2003-2005

Level	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
	Monthly average prices (Rp/kg)											
Farm gate	2,587.4	2,489.8	2,408.2	2,399.0	2,355.1	2,512.7	2,670.7	2,514.2	2,555.5	2,584.9	2,886.8	3,325.5
Wholesale	3,679.9	3,448.8	3,387.4	3,378.6	3,300.2	3,364.6	3,755.8	3,717.2	3,763.3	3,747.1	4,079.8	4,365.8
Monthly average as % of overall average[a]												
Farm gate	0.99	0.95	0.92	0.92	0.90	0.96	1.02	0.96	0.98	0.99	1.11	1.28
Wholesale	1.00	0.94	0.92	0.92	0.90	0.92	1.02	1.01	1.03	1.02	1.11	1.19

[a] Calculated by dividing each monthly average by the overall mean of crop prices (Rp2,607.5 at farm gate level) and (Rp3,665.7 at wholesale level)

Source: Direktorat Jenderal Tanaman Pangan dan Hortikultura

Appendix 2. Farmer, Scientist and Extension Questionnaires

Farmer Questionnaire

Commodity ____________________

Respondent **Interviewer**

Name: ____________________ Name: ____________________
Location: ____________________ Date: ____________________
Education: ____________________
Years in farming: ____________________

1. What are your current crop management practices for the following:

   a) Land preparation? ____________________
   b) Crop establishment? ____________________
   c) Water management? ____________________
   d) Potato storage (percent stored)? ____________________
   ____
   e) Pest management (Fill in table below)

Control method	Frequency (per cropping season)	Quantity	Remarks (e.g., brand names)
Chemicals			
Insecticides:			
Field Storage			
Fungicides			
Biological			
Botanical			
Others (specify)			

2. Production cost structure

Cost component	Quantity	Price per unit
Pre-harvest costs:		
Seeds/planting materials		
Fertilizer		
Pesticides		
Labor		
Other		
Post-harvest costs:		
Labor		
Pesticides		

Cost component	Quantity	Price per unit
Other		
Total production and storage costs		

3. What was your yield per hectare for this crop last year? ____________________ and your average over the last 5 years? ________________

4. What was your average annual storage loss (%) due to tuber moth last year? ________________ and over the last 5 years? ________________

5. What are the preferred varieties in your area? ____________________

6. What is/are your source/s of seeds/planting materials? ____________________

7. What are your market outlets? (√)
   a. traders ______________
   b. direct selling ______________
   c. contract growing ______________

Scientist Questionnaire

Commodity ____

Respondent

Name: ____
Position: ____
Specialization: ____
Education: ____
Years of experience on the crop: ____________________________

1. What will be the most likely (lowest, highest) expected reduction (%) in storage loss per ton of potatoes if the genetically modified crop is developed and adopted (for those farmers who adopt it in the region)?

Percent reduction in storage loss		
Lowest	**Most Likely**	**Highest**

Justify your choice:
____
____

2. What percent of total variable costs is currently represented by each variable input (hired labor, fertilizer, etc.) What is your estimate of the percent change in cost (per hectare) (if any) for each of the inputs if the genetically modified crop is adopted?

Input		**Most Likely Cost Change**			
	Current Cost Share	**Decrease**	**No Change**	**Increase**	**Percent Change**
Variable (per ha)					
Hired labor					
Fertilizer					
Pesticides					
Field storage					
Seeds					
Marketing					

3. What is the probability (percent chance) of biotech research developing a solution with a commercially acceptable level of effectiveness against tuber moth?

____

Justify your choice:

____

____

4. How many years will it take to complete the technology development and to meet the various regulatory requirements?

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**...**
Technology development											
Regulatory											
Contained											
Limited field trial											
Multi-location field trial											
Food safety assessment											
Apply for commercialization											

Explain briefly your background experience to justify your choices:

____

____

____

____

5. What are the expected costs involved in developing the technology and meeting the regulatory requirements?

Cost (USD)											
Technology development											
Regulatory											
Contained											
Limited field trial											
Multi-location field trial											
Food safety assessment											
Apply for commercialization											
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**...**

Explain briefly your background experience to justify your choices:

____

____

____

____

6. Which variety do you intend to put this technology? {Encircle answer(s)}

			Remarks
Variety type	hybrid	saved seeds/OP	
Variety source	public	private	
Variety use	fresh	processed	
Target market	domestic	export	

7. What are the expected unintended environmental effects? (check √ if a concern and explain in one sentence what the concern is)
   a. gene flow

   ____

   ____

   b. reduced biodiversity

   ____

   ____

   c. harms non-target organisms

   ____

   ____

   d. others (specify)

   ____

   ____

8. How often do the farmers purchase certified planting materials? ____________

9. How often do the farmers exchange planting material (outside of the formal seed system)? ____________

10. Would the farmers be able to segregate *Bt* potato variety from the same non-GM variety? ____________

11. Would the farmers be willing to pay a premium for the certified planting material of *Bt* potato and what % is it? ____________

Extension Expert Questionnaire

Commodity ______________________________

Respondent

Name: ____________
Date: ____________
Location: ____________
Years of experience with potato: ______

Interviewer

Name: ____________
Date: ____________

1. What is your estimate of the average annual potato storage loss (%) due to tuber moth last year? ________ and in the last 5 years? ________

2. What are the preferred varieties in your area? ____________

3. What are the main sources of seed? ____________

4. What are the chances (%) that if a transgenic (*Bt*) potato were developed with resistance to tuber moth, that it would pass the regulatory requirements and be commercialized? ____________

5. What would be the maximum percentage of potato area expected to be covered by the biotech crop? ________ How many years would it take to reach maximum adoption once the crop is commercially released? ____________

6. Do you expect an increase (decrease) in area devoted to potato over the next 10 years? If so, by what percent per year? ____________

Chapter 9

Implications of Regulatory Costs for Ring Spot Virus Resistant Papaya in the Philippines

J.M. Yorobe, Jr. and T.P. Laude

Introduction

The adoption of transgenic crops has contributed significantly to agriculture by increasing productivity though improved management of biotic stresses. The economic opportunities and challenges posed by the new technology are of continuing interest to many countries where food supplies is low and poverty in agriculture is pervasive. There is now a rapid adoption of biotech crops reflecting the many benefits realized for both large and small farmers in industrial and developing countries (James, 2008). The prospects for biotech crops look even more promising as new traits are being developed by national research institutes in more crops of major economic importance. After the successful commercialization of the *Bt* and herbicide tolerant corn in the Philippines, biotech research has now intensified on rice, banana, abaca, coconut, papaya, eggplant, and mango.

The development and commercialization of these transgenic crops is not costless though, as long and costly development and regulatory processes are necessary to ensure the stability and safety of the technology (Falck-Zepeda et al., 2003). The large investment in developing the technology can sometimes stifle technology innovation making it not available for commercialization. A study by DiMasi et al. (1991) in the United States found that only 21.5 percent of the pharmaceutical drugs under development at an average cost of about USD800 million per compound make it to the market. The need for biosafety regulations to minimize the risk of food problems and environmental damage drives the regulatory costs of agricultural biotechnologies to be substantial. Excessive regulations, however, can provide a disincentive for small farmers to adopt the new product because of the resulting high price. The size of the total product development cost has also become a serious issue in developing countries where investments in research are limited. The innovative effort may be criticized as too expensive and time consuming without regard to the potential benefit that might accrue from the innovation (Pray et al., 2005).

To address these problems and mitigate production losses attributed to the papaya ring spot virus (PRSV) in the Philippines, a transgenic variety resistant to the virus is presently under development at the Institute of Plant Breeding, University of the Philippines Los Baños (IPB-UPLB). This chapter aims to examine the technology's development and regulatory costs and overall benefits to society. The costs represent the total social costs including the sum of all opportunity costs introduced by the development and regulation of the technology. Social costs may be classified as private or public costs depending on who bears them. Private costs are borne by firms or individuals in society while public costs are those incurred by society as a whole. Biosafety regulations are necessary but if unduly restrictive, might also impose costs that could pose as barriers to the development of biotechnology products. Previous studies have shown that these costs depend to a large extent on the type of regulatory framework adopted, commodity, and institution (Pray et al., 2005; Yorobe, 2006; Ramon and Manalo, 2006). In China, the total cost of regulatory compliance for the approval of a new GM field crop was USD65,459 per event for private companies compared to only USD53,287 for government institutes (Pray et al., 2006). However, neither of these costs appears unreasonably high. These costs have not been estimated for the Philippines, providing part of the incentive for the current study.

The Papaya Ring Spot Virus (PRSV) in the Philippines

PRSV is a major limiting factor to papaya production in the Philippines. The epidemic of the virus caused by PRSV in the Southern Tagalog region played havoc in papaya orchards there. The virus almost wiped out the industry in Cavite, where 60 to 100 percent disease occurrence affected most of the commercial papaya orchards (Opina, 1988). Since its detection in 1982, the virus has spread over long distances throughout the country causing a dramatic decline in productivity. It is reportedly widespread in mainland Luzon, covering the provinces of Cavite, Batangas, and Laguna, and islands of Palawan, Mindoro, and Marinduque, the Visayan group including Negros, Leyte, Aklan, and Panay, and lately claimed in Cotabato in Mindanao (Magdalita, 2000). PRSV incidence was first observed in Silang, Cavite in 1982, and is said to be the most destructive of the viruses and diseases infecting papaya plantations in the Philippines.

Infected young fruit develop small light green concentric rings on the surface, which become darker green and less distinct as they become older. The infected ripe fruit have yellow concentric rings with a green center. Vein clearing and chlorosis appear on the infected leaves. Severely infected plants have distorted leaves. Oily streaks appear on petioles and on the trunk (Sumalde et al., 1995).

The virus is readily transmitted mechanically from infected to healthy plants. It is non-seed borne but efficiently transmitted by sap inoculation and by several species of aphids in a non-persistent manner. PRSV is rapidly spread within a short period of time over long distances.

Among the methods to prevent and reduce the spread of the disease are quarantine, rouging and sanitation, cross protection, use of tolerant as well as resistant varieties, and integrated disease management strategies (Magdalita, 2000). As a quarantine measure, the Bureau of Plant Industry has banned the transport of papaya seeds and seedlings from Luzon to virus-free areas.

Tolerant varieties make some yield possible despite the presence of the virus. Scientists at the IPB continue to search for resistant varieties. *Sinta* is the first Philippine-bred hybrid papaya that is moderately tolerant to PRSV, planted by farmers in mainland Luzon. Hawaii is presently growing a truly resistant variety, Rainbow, developed through genetic transformation. A transgenic PRSV-resistant cultivar has already been developed by IPB scientists, but has yet not been commercialized in the Philippines. Lastly, disease management strategies are being recommended to avoid PRSV infection. These include planting papaya in areas where there are barrier plants that can disrupt the flight of aphid vectors; planting in March when the population of aphids is low; removing all infected plants in the area before planting; avoiding intercropping papaya with cucurbits which are hosts of the virus; removing weeds with virus-like symptoms around the area; and planting papaya in relatively isolated areas. In addition, papaya should be treated as an annual rather than perennial crop (Villegas, 1995).

Traditional methods to control PRSV infection in papaya plantations have had limited success because the virus is efficiently spread from plant to plant by about 60 species of aphids and transmission is "non-persistent," meaning the aphids need to feed on a PRSV-infected plant for only a few seconds to pick up the virus. This makes it virtually impossible to control the virus by insect control or by discarding diseased plants. There is no known natural resistance to the virus, although tolerant varieties with reduced symptoms have been identified. In the Philippines, the *Sinta* variety has been a commercial success, but breakdown of resistance and loss of its effectiveness were reported as early as two years after the release of the hybrid. Production under netting is an option but this requires a large initial capital investment, which most small-scale producers can not afford. Considerable variation exists in the genomic sequences of various strains of PRSV. Because of these limitations, scientists have turned to genetic engineering and the use of the PRSV "coat protein resistance" strategy to develop transgenic PRSV-resistant papaya.

Methodology

Data on development and regulatory costs were collected from secondary sources and through personal interviews with scientists at the IPB-UPLB, funding agencies, and regulators from the Department of Agriculture Bureau of Plant Industry (DA-BPI) and the National Committee on Biosafety of the Philippines (NCBP). The secondary data include enterprise budgets, yield, production, prices, research funds and expenditures by agency, and other related economic data on the papaya industry. Two components of social costs were considered: (a) the costs of real resources (direct) in the development of the variety and biosafety regulatory dossier and (b) government costs in regulating the technology. The direct costs are those incurred for personnel, supplies and materials, travel, purchase of equipment, provision and use of facilities, and other productive inputs necessary to develop the variety and regulatory dossier while the government costs are administrative expenses and fees incurred by the regulatory body to review and approve an application and monitor the trials.

Since the PRSV-resistant technology has not yet been released for commercial use in the Philippines, the benefits and part of the costs were projected using an *ex-ante* economic surplus framework. The economic benefits base model assumptions and parameter values were based on those already presented in Chapter 3 and listed in Appendix Table 1, with one difference. Chapter 3 presents a small open economy model in a partial equilibrium framework as there is a small amount of Philippine (*Solo*) papaya in the international trade. On the other hand, this chapter assumes a closed economy model since it appears that the commercialization of the PRSV-resistant technology is intended to be grown primarily in Luzon for domestic consumption. For the conceptual issues on this model, reference is made to Alston et al. (1995).

Results and Discussion

Cost data for the development and regulation of the PRSV-resistant papaya were collected through a series of interviews with scientists, regulators and research/funding institutions, namely: IPB, DOST-PCARRD, UPLB, ISAAA and ABSPII. Since the PRSV-resistant technology has just completed the confined trial stage, the actual development and regulatory cost data were only available for the period 1999-2008. For the period 1999-2009, the cost data that were available were mainly disaggregated by line item similar to those shown for development cost in Table 1. The actual costs were converted into values at 2008 constant prices for comparison purposes.

Table 1. Product development and regulatory costs of the PRSV-resistant papaya in the Philippines, 1999-2009.

Stage	Amount	Constant cost at 2008 price	% to total cost
PRODUCT DEVELOPMENT COSTS	(PhP)	(PhP)	
Discovery			
Gene isolation and cloning	945,000.00	1,013,235.05	
Transformation, importation and selection of primary transformants (T_0)	1,135,000.00	1,229,544.16	
Sub-total	2,080,000.00	2,242,779.21	7.66
Further breeding and selection			
T_1 and T_2 greenhouse efficacy testing and event selection	2,294,526.33	2,197,721.67	
Sub-total	2,294,526.33	2,197,721.67	7.50
Confined trial			
Efficacy testing and horticultural evaluation	5,360,194.44	4,863,142.05	
Training and coordination costs	275,815.00	250,238.59	
Sub-total	5,636,009.44	5,113,380.65	17.46

Stage	Amount	Constant cost at 2008 price	% to total cost
Multi-location trial (two sites; one season)			
Efficacy testing and horticultural evaluation -NTC	3,025,000.00	3,025,000.00	
Sub-total	3,025,000.00	3,025,000.00	10.33
Propagation or commercial release			
Seed increase and variety registration	440,000.00	440,000.00	
Sub-total	440,000.00	440,000.00	1.50
Total Product Development Costs	13,475,535.71	13,018,881,53	
REGULATORY COSTS			
Discovery			
Preparation of regulatory dossier	10,000.00	10,722.06	
Containment cost – P2 and BL2 facility	504,166.67	546,163.16	
Sub-total	514,166.67	556,885.22	1.90
Further breeding and selection			
Partial molecular characterization – insert selection and nptII protein expression	2,190,516.94	2,175,111.77	
Monitoring and termination costs	20,000.00	19,156.21	
Sub-total	2,210,516.94	2,194,267.98	7.49
Confined trial			
Preparation of regulatory dossier	687,500.00	719,542.11	
Partial molecular characterization and genetic stability testing; transcript and protein detection	4,163,285.13	4,103,598.57	
Other environmental safety studies	4,425,278.00	4,361,835.40	
Confinement facility cost	308,430.00	340,044.08	

Stage	Amount	Constant cost at 2008 price	% to total cost
Monitoring and termination costs	50,000.00	55,125.00	
Coordination costs	184,875.00	184,875.00	
Sub-total	9,819,368.13	9,765,020.16	33.33
Multi-location trial (two sites; one season)*			
Regulatory filing, assessment and approval of permit	282,000.00	282,000.00	
Other environmental safety studies	1,600,000.00	1,600,000.00	
Other food/feed safety studies	630,000.00	630,000.00	
Confinement facility cost	50,000.00	50,000.00	
Monitoring and termination costs	330,000.00	330,000.00	
Coordination costs	184,875.00	184,875.00	
Sub-total	3,076,875.00	3,076,875.00	10.50
Propagation or commercial release*			
Preparation of regulatory file application	352,000.00	352,000.00	
Application, assessment and approval of permit	330,000.00	330,000.00	
Sub-total	682,000.00	682,000.00	55.56
Total Regulatory Costs	16,302,926.74	16,275,048.36	
TOTAL DEVELOPMENT AND REGULATORY COSTS	29,778,482.51	29,293,929.90	100

*Planned activities with estimated budget

Source of data: ABSPII

At constant 2008 prices, the total technology development and regulatory costs relating to PRSV-resistant papaya amount to PhP29.29 million (USD658.6 thousand), representing the estimated total investment required to secure approval of the event for commercialization. This is lower compared to the development and regulatory costs incurred for the delayed ripening papaya event in the Philippines, which amounted to PhP39.9 million (Ramon and Manalo, 2006).

The costs of developing the PRSV-resistant technology account for 44 percent of the total cost and regulatory activities, 56 percent. The major expenditure items including personal services, supplies, and repairs and maintenance represented more than 80 percent of the total development cost. Costs of laboratory supplies in conducting the transformation and the required tests as well as equipment maintenance comprised a substantial part of the cost (11 percent). The personal services refer to salaries of hired personnel and honoraria of scientists while services account for contract labor and other specialized services. The overhead costs on the use of office and facilities at IPB are imputed and included under the said costs. As more data are required, the time and cost of meeting the regulatory requirements for other events may substantially increase.

The regulatory costs were divided into four parts to conform with the major stages of bioengineered product development described in Chapter 1, namely: laboratory/greenhouse, confined field trial (limited field release), multi-location field trial, and commercialization. These do not include the post-commercialization regulatory costs on monitoring pest resistance in farmers' fields. Because no PRSV coat protein is expressed in the bioengineered PRSV-resistant papaya, costs associated with toxicity and allergenicity testing were not included. There was also difficulty in disaggregating joint costs such when the activity may be classified as both development and regulatory particularly in the laboratory/greenhouse stage. For this reason, only the costs for required regulatory tests were included at each stage including the depreciation of facilities and overhead costs for the use of office and laboratory facilities. The actual costs were only available up to the confined trial stage. For the succeeding activities/stages, the costs were anticipated *ex-ante* for multi-location field trial, and commercialization using 2008 prices.

The confined trials and multi-location field trial costs account for more than 78 percent of the total regulatory costs (about PhP12.8 million, or USD287.8 thousand) due to the expected large outlay on development of regulatory file required prior to commercial release and public information campaign. The former includes trait efficacy and horticultural performance under field condition, full molecular analysis and relevant food safety studies while the public information campaign refers mostly to publication, production of communication materials, workshops, and monitoring and analysis of media and public opinion. The risk and environmental assessments are part of these costs. The total regulatory cost of PhP16.3 million exceeded the cost of regulating rice biotechnology events in the Philippines, which ran to about PhP6.1 million in 2006 (Yorobe, 2006).

Figure 1 presents the total development and regulatory costs of the PRSV-resistant papaya event annually from 1999 to 2008. The cost was highest in 2008 which included the two confined field trials and molecular characterization. Least expenditures can be observed during the initial development period of 1999-2000 covering preparations for application for contained trials and initial research activities (cloning and transformation). This is attributed to the establishment of the Papaya Southeast Asian Network (http://www.isaaa.org) which facilitated the internships of two Philippine scientists to do the cloning activities at Monsanto laboratory in St. Louis, Missouri, USA and the *Agrobacterium*-mediated transformation at MARDI laboratory in Malaysia. The costs were also large in 2006 during the laboratory/greenhouse evaluation and line selection periods.

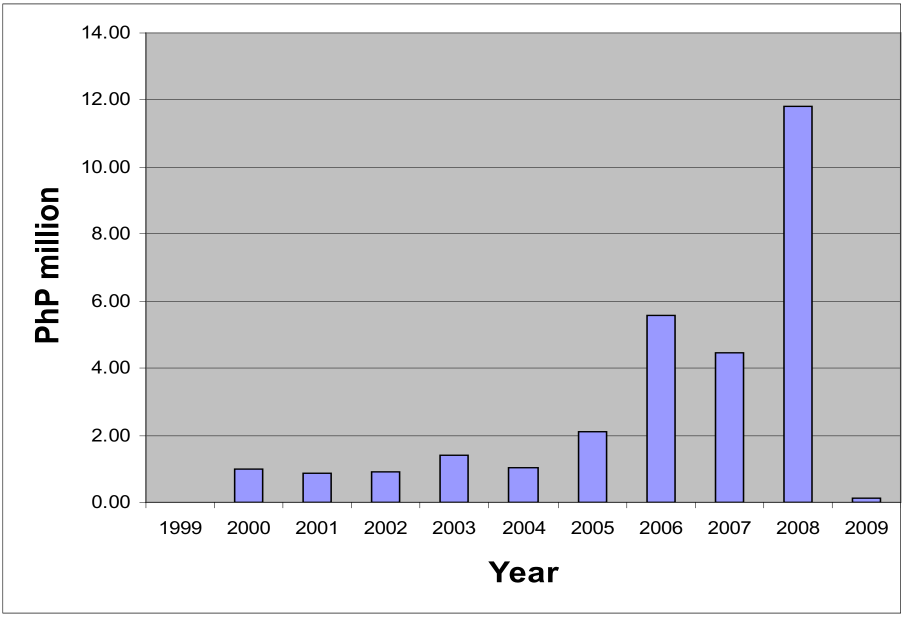

Figure 1. Development and regulatory costs of PRSV-resistant papaya in the Philippines

Benefits of the PRSV-Resistant Papaya Technology

The significance of the estimated development and regulatory costs can not be appreciated without examining the potential benefits that accrue with technology adoption. To estimate these benefits, this study employed the economic surplus approach already discussed in Chapter 3, assuming a closed economy in this case and considering only the areas planted to papaya for the domestic market. The internal rates of return on research and regulatory investments were also calculated to determine how the alternative scenarios would impact on the incentive to develop the PRSV-resistant papaya technology.

The results revealed that the PRSV-resistant technology would likely bring about substantial welfare benefits to producers and consumers. If released in 2010, the total economic surplus due to technology adoption is estimated at PhP9,823.1 million (before discounting) for the period 1999-2020, with the benefits accruing more to the consumers than producers (Table 2). The larger welfare benefit to consumers is realized due to the decrease in papaya prices in the market brought about by the increase in output. Even with the PhP29.3 million development and research costs, the net present value of the stream of benefits to society was valued at PhP4,125.97 million (discounted at 5 percent). These results clearly demonstrate the technology's economic significance in the development of the Philippine papaya industry. The high internal rate of return (IRR) of 84.31 percent indicates a good incentive to actually pursue the commercialization of the technology. This means that every peso invested to produce PRSV-resistant papaya provides a return of PhP84.30 (or about USD1.91).

Four hypothetical scenarios were considered to test the sensitivity of the model and estimate the impact on the motivation to develop and regulate the PRSV-resistant technology. These scenarios were as follows:

1. An increase in the development and regulatory cost of 20 percent in 2008-2009 - The technology is currently under regulation whereby any additional data requirements or applications can substantially increase the total development cost. Seed cost was also assumed to increase by 20 percent.
2. A development and regulatory cost decrease of 20 percent.
3. A five-year delay in the commercialization of the technology, which may be brought about by more stringent regulations or the extended time necessary to comply with all the regulations.
4. A simultaneous 20 percent increase in development and regulatory costs and a five-year delay in commercialization.

Table 2. Returns to the PRSV-resistant technology under various scenarios, Philippines

Scenario	Year of commercialization	Development and regulatory costs (PhP million)	Impact on surplus (PhP million)		NPV of net benefit (PhP million)	IRR (%)
			Consumers	Producers		
Baseline	2010	29.29	5,613.20	4,209.90	4,125.97	84.31
20% increase in development and regulatory costs	2010	31.68	5,613.20	4,209.90	4,124.51	84.17
20% decrease in development and regulatory costs	2010	26.90	5,613.20	4,209.90	4,127.43	84.44
Five-year delay in commercialization	2014	29.29	2,941.51	2,206.13	1,961.84	53.29
Simultaneous 20% increase in development and regulatory costs and five-year delay in commercialization	2014	31.68	2,941.51	2,206.13	1,960.37	53.05

If regulatory costs in 2007-2008 were increased or decreased by 20 percent, the effect on the internal rate of return and the benefits will be imperceptible considering that the technology is already in the later stages of the development process. The impact of these cost changes will be borne more by the producers than the consumers who would realize benefits or losses of not more than PhP1 million for the cost decrease or increase, respectively. While the likely effect of more stringent regulation in the last two years may not be substantial, it may delay the commercialization process and increase the seed cost to farmers. A larger impact is observed when commercialization is delayed for five years. For this scenario, both producers and consumers lose, with a total net benefit loss of PhP4,675.5 million. The internal rate of return also substantially decreases to 53.29 percent.

Summary and Conclusions

The economic contribution of the Philippine papaya industry is significantly diminished by damage from PRSV, to which presently all available commercial varieties are highly susceptible or at best tolerant to the disease. To address this concern, IPB-UPLB has been developing and undergoing regulatory approvals for a transgenic papaya variety with higher level of resistance to PRSV than what currently available commercial variety can provide. This study assessed the various development and regulatory costs and benefits of the PRSV-resistant papaya technology in the Philippines in order to provide valuable information to farmers, researchers, and policy makers.

The PRSV-resistant papaya technology is estimated to take 12-14 years before it can be commercially released. The discovery and development stages which include cloning and transformation and further breeding and initial candidate event selection, respectively, have already taken place from 2000-2006. Further product testing and regulatory compliance is estimated to take another six years. The total development and regulatory costs will amount to at least PhP29.29 million or an average of PhP2.66 million per year (or about USD658.6 thousand total, USD59.8 thousand average per year). The development cost comprises 44.4 percent of the total cost and regulatory compliance cost, 55.6 percent. The major cost items were personnel services, supplies, and repair and maintenance at the development stage and confined and multi-location field trials at the regulatory phase. The costs of the tests to comply with the regulations contribute substantially to total costs.

The estimated total development and regulatory costs are small when compared to the potential benefits that may accrue from technology adoption. The net benefits to society with technology adoption is estimated to amount to PhP9,823.1 million with an internal rate of return of 84.3 percent. At this IRR level, there is a strong incentive to commercialize the technology. This analysis also reveals that consumers are more likely to benefit more than producers. A delay in commercializing the technology will thus result to substantial welfare losses to both producers and consumers. It also diminishes the internal rate of return by as much 31 percent. The economic impact of this scenario is far greater than the increase in the regulatory costs.

The major implication of this study is that investing more in the development and regulatory activities that facilitate the early commercialization of the PRSV-resistant papaya technology will result in substantial payoffs to farmers and consumers. Streamlining the regulatory process to reduce delays would hence prove to be beneficial to society and increase the incentives for innovators.

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Appendix 1.

Table A-1. Assumptions and parameter values in the base model

Item	Value	Source
Price elasticity		
Supply	0.80	Yorobe (2006)
Demand	- 0.60	Laude (2006)
Research		
Commercialization (year)	2010	
Cost (PhP million)	20.1	
Adoption rate (%)		Yorobe (2006)
Initial (2010)	30	
Maximum (2016)	90	
Expected yield increase per hectare (%)	77	Yorobe (2006)
Change in cost per hectare (%)	8	Yorobe (2006)
Probability of research success (%)	83	Yorobe (2006)
Technology depreciation (linear, starts in 2017)	10	Yorobe (2006)
Papaya production ('000 mt) base year 1998	67.89	BAS
Papaya wholesale price (PhP/kg)	20.19	BAS
Discount rate (%)	5	

Chapter 10

Level and Implications of Regulatory Costs in Commercializing *Bt* Eggplant, Virus Resistant Tomato, and *Bt* Rice in the Philippines

J.C. Bayer, G.W. Norton and J. Falck-Zepeda

Introduction

Agricultural biotechnologies potentially have significant benefits for developing countries, but many countries lack complete regulatory processes to allow their release. A suitable regulatory process is necessary for the safety of those who consume genetically modified organisms (GMOs) as well as for the environment that might be indirectly affected by the products. Each nation needs a set of regulations that are both protective and efficient. In setting regulations, countries must be cautious but not overly restrictive unless they intend to delay or even forgo the benefits of the technology.

Costs associated with implementing a regulatory process for a specific transgenic product can be a significant portion of the total costs of bringing the product to market (Jaffe, 2006; Pray et al., 2005). Some of these costs involve direct expenditures and some are opportunity costs of benefits foregone from the product being delayed in moving into commercialization. In evaluating the potential net benefits of genetically modified crops, it is important to understand the magnitude of these costs, both for countries still in the process of designing their regulatory processes, and for those implementing one. This paper identifies the direct costs and opportunity costs of regulation for three transgenic products in the Philippines: *Bt* eggplant, *Bt* rice, and multiple virus resistant (MVR) tomatoes. It finds that direct regulatory costs, while significant, are similar in magnitude or smaller than the research costs for technology development. However, both research and regulatory costs are overshadowed by even a relatively short delay in product release, which might be caused by an unexpected regulatory delay.

Regulatory costs vary by country and for conditions specific to each organism. For example, costs can be affected if certain biosafety tests for a product have already been conducted in other countries, if the product has been developed and tested in the public versus the private sector, if the product will be exported, and if the product is consumed as a food. Regulatory costs for the three crops mentioned above are compared among themselves and to those of papaya ring spot virus resistant (PRSV-R) papaya which were discussed in Chapter 9 to illustrate how different characteristics affect the costs.

Methods

The steps in the regulatory process and its direct costs and timing were defined through review of documents and interviews with government officials, researchers, and other experts in the regulatory process for biotech products in the Philippines. Those interviewed included: (a) scientists and experts from the Institute of Plant Breeding at the University of the Philippines Los Baños (IPB-UPLB), the International Rice Research Institute (IRRI), and the Philippine Rice Research Institute (PhilRice), and (b) representatives from the Department of Science and Technology (DOST) and from the National Committee on Biosafety of the Philippines (NCBP). The interviews helped identify circumstances in which biosafety and other tests conducted in other countries are accepted in the Philippines and how that acceptance affects the costs. The costs and time associated with each of the following steps were assessed:

1. Preparing a project proposal for submission to the Institutional Biosafety Committee (IBC),
2. Submitting a proposal to the IBC which conducts a biosafety assessment and then endorses it to the National Committee on Biosafety of the Philippines (NCBP),
3. Applying to the NCBP for permit to conduct contained testing,
4. Applying to the Department of Agriculture, Bureau of Plant Industry (DA-BPI) for a field testing permit after contained testing is complete and successful (tests relate to gene flow, food safety, toxicity, efficacy, and other environmental tests), conditional on endorsement by the NCBP,
5. BPI creates a Scientific and Technical Review Panel (STRP) concurrent with public notification by the IBC, and the STRP evaluates potential adverse effects to humans and the environment,

6. Risk assessment by STRP and BPI-Core Biotechnology Team (BPI-BCT),
7. Conduct of single field and then multiple location field testing with each field evaluated separately once there is receipt of a field test permit, and
8. Obtaining a permit for release for propagation and commercialization.

Each step in the regulatory process allows for increased exposure of the transgenic or biotech product to people and to the environment. A detailed description of the Philippine regulatory process is presented in Chapter 1.

Once estimates of the costs of these steps were collected, economic surplus models were run to evaluate the economic impacts of introducing each of the transgenic products. These models built on previous studies by Mamaril and Norton (2006) for rice, Mamaril (2005) for tomato, Yorobe (2006) for papaya, and Francisco (2006) for eggplant. The results of their analyses were duplicated. Their models assumed small open economies for papaya and rice and closed economies for tomato and eggplant. Assumptions in their models were then updated and regulatory costs were introduced in addition to research costs. The models were run allowing basic assumptions to vary, including regulatory costs and the time lags for regulatory steps. Assessment of net benefits under various scenarios allowed for calculation of opportunity costs associated with regulatory time lags.

Results

The major activities for which there are significant regulatory costs can be categorized into four groups: a) contained laboratory and greenhouse/screenhouse testing, b) confined field trials, c) multi-location open field trials, and d) other commercialization costs (Table 1). Based on information from the sources described above, total estimated regulatory costs vary from USD248,500 for papaya to USD690,000 for rice (Table 2). The two field trial activities represent the majority of the costs. Scientists and other experts projected the time required for each step. The number of years for each regulatory activity differs by commodity due to factors such as differing stages in which the technologies were received by scientists in the Philippines, and the length of time it takes to obtain one generation of the crop. Details for each crop are given in Bayer (2007). Total estimated research costs are similar in size to regulatory costs, and vary from USD120,000 for papaya (significant research results transferred in from abroad) to USD890,000 for rice.

PRSV-R papaya, MVR tomato and *Bt* eggplant are being developed and tested by researchers and scientists at the University of the Philippines Los Baños (UPLB). Confined field trials of transgenic or bioengineered papaya and eggplant have been completed. It is expected that regulatory costs for MVR tomato will follow a similar pattern to that of *Bt* eggplant, except for the toxicology package which will entail substantial cost. *Bt* rice has been developed and tested at the Philippine Rice Research Institute (PhilRice) in Nueva Ecija. Much of the regulatory activity on *Bt* rice occurred over a three-year period. Confined screen house testing in the first year cost USD20,800, while the second year contained field testing cost USD446,700. Multi-location field testing is projected to cost USD105,000 per year. Commercialization and public release were projected to cost USD13,180 (Table 1).

Table 1. Regulatory costs (USD) and time

	Cost/year	No. of years	Total cost
Bt eggplant			
Laboratory/greenhouse	90,000	2	180,000
Confined field trial	100,000	1	100,000
Multi-location field trial	100,000	1	100,000
Commercialization costs	95,000	1	95,000
MVR tomato			
Laboratory/greenhouse	90,000	2	180,000
Confined field trial	100,000	1	100,000
Multi-location field trial[1]	100,000	1	100,000
Commercialization costs	95,000	1	95,000
Bt rice			
Laboratory/greenhouse	20,800	1	20,800
Confined field trial	446,700	1	446,700
Multi-location field trial[1]	105,000	2	210,000
Commercialization costs	13,180	1	13,180
PRSV-R papaya			
Laboratory/greenhouse	16,000	3	48,000
Confined field trial	43,300	2	86,600
Multi-location field trial[1]	41,700	2	82,400
Commercialization costs	31,500	1	31,500

1 This multi-location biosafety field trial involved two sites and two seasons during the year. It is part of a broader variety trial that involved more sites and years. The costs of these additional variety trials are not included here as they would be incurred anyway.

A large set of assumptions is required for an economic surplus analysis, and several of the most important ones are listed in Table 2. Rice production is substantial in the Philippines and adoption of *Bt* rice is projected to be significant despite a relatively low impact on yield. Adoption is projected to be more gradual however, than for the other products, perhaps due to the small yield effect. Because *Bt* rice exists and is part way through the regulatory process, the experts were confident it would be successful and gave it a probability of research success of 1. MVR tomato is the product that is farthest away from the market.

Table 2. Basic assumptions in economic surplus models

	***Bt* eggplant**	**MVR tomato**	***Bt* rice**	**PRSV-R papaya**
Quantity (mt)	182,750	152,690	10,500,000	159,000
Price (USD/mt)	200	215	180	363
Supply elasticity	0.5	0.75	0.95	0.80
Demand elasticity	-0.80	-0.45	-0.30	-1.0
Change in yield (%)	40	67	2.4	77
Change in costs (%)	-16	-10	0	8
Probability of success (%)	70	50	100	83
Maximum adoption (%)	50	70	66	80
Years to first adoption	9	12	8	10
Years to maximum adoption	14	14	15	15
Total research cost (USD)	580,000	434,000	888,729	120,370
Total regulatory cost (USD)	475,000	475,000	690,680	249,500

From the inception of the research to over 20 years, the net present value (NPV) of benefits minus costs (discounted at 5 percent) varied from USD17 million for tomato, USD20 million for eggplant, USD220 million for rice to USD250 million for papaya (Table 3). A variety of sensitivity analyses were conducted, such as varying the elasticity of supply and the discount rate. They had predictable effects on benefits, such as a smaller supply elasticity or a smaller discount rate increasing benefits significantly.

Table 3. Economic surplus results (USD'000)

	Bt eggplant	MVR tomato	*Bt* rice	PRSV-R papaya
Total economic benefits	40,814	34,240	481,723	171,976
NPV of benefits minus costs (at 5% discount rate)	20,466	16,748	220,374	90,766

However, the key sensitivity analyses were to evaluate the effects of increasing regulatory costs and altering the time required for regulatory approval and hence adoption of the technologies by farmers. Even when regulatory costs were doubled or quadrupled, effects on total net benefits in each case were small (less than USD1 million change in NPV in most cases) compared to the losses (opportunity costs) that were incurred when commercialization was delayed by one, two, or three years due to regulatory delays beyond the expected timeframe (Table 4). In each case, several million dollars were lost.

Table 4. Sensitivity analysis (NPV of benefits minus costs under varying assumptions on regulatory costs and time lags) (5% discount rate, USD '000)

	Bt eggplant	MVR tomato	*Bt* rice	PRSV-R papaya
Increases in regulatory costs by:				
75%	20,551	16,530	219,977	90,633
200%	20,129	16,165	219,316	90,417
400%	19,435	15,582	218,258	90,097
Regulation time lag (delayed commercialization)				
1 year longer	14,707	106,567	193,926	66,363
2 years longer	8,932	4,855	168,738	46,061
3 years longer	4,242	1,111	144,749	29,540

Some of the potential sources of regulatory delays include the repetition of tests, review time and information requests by regulators. Another is lack of clarity with respect to the requirements. One example of something that can cause a time delay is an NCBP request for more information from a previous generation. Under the containment rules, it is required that each generation, T_n, of the plant be destroyed once any and all tests are completed and the next generation, T_{n+1}, has been produced. In the instance of an information request from the T_0 generation when the scientists are testing the T_3 generation, T_3 then reverts to being the T_0 generation and three more generations of the plant must be produced, resulting in a time loss of three growing seasons. With a three-month growing season, the result would be a loss of one year. In the case of a one year growing season such as with papaya, the result would be a loss of three years.

The duplication of tests is another potential source of time delay. An example of this is the agro-morphology, or parent to progeny, test that is being duplicated by separate tests. A lack of clarity creates time delays by encouraging scientists to gather extra information in anticipation of possible later requests by regulators. An inherent delay is also created by the NCBP review panel schedule, as it meets only once a month. When information is requested about a product under review, there is a delay of at least one meeting, implying a delay of at least one month. In many cases, this delay can be avoided by the attendance of representatives from the IBC together with the researcher/ applicant at the NCBP meeting so they can answer questions the panel may have about the product that do not require further testing.

The regulatory timeline is also affected by the source of the product. If a product has previously undergone biosafety testing in another country, in some cases it may be possible to skip certain early laboratory tests (before the confined field trial), although all tests beginning with the confined field trial will of course need to be performed as they are location specific. Another potential source of time savings can come from specialization. As more product reviews are undertaken, it may be possible to hire specialists for completing regulatory paperwork and corresponding with regulatory agencies. Over time, as scientists and regulators become more experienced and more products make it through the various regulatory steps, all people involved in the process should become more proficient.

These examples are not meant to be exhaustive or to single out NCBP as BPI is also involved in the regulatory process. It makes no difference where delays occur in the process as they are equally costly in terms of foregone benefits.

Conclusion

The key contributions of this paper are to document the nature and size of regulatory costs for different types of genetically modified crops in a developing country setting, estimate opportunity costs of delays for comparative purposes, and summarize potential impacts of several different transgenic products. The Philippines is an excellent case study because it has several transgenic products already undergoing the regulatory testing and approval process and has already released *Bt* corn.

A study in India by Pray et al. (2005) previously found private regulatory costs for *Bt* cotton in the neighborhood of USD2 million. That study notes, however, that public sector regulatory costs can be lower, in part because the private sector must contract with the public sector for some of the regulatory steps. Our results confirm their hypothesis, with regulatory costs running less than USD1 million. Especially for products for which many of the basic laboratory biosafety tests have already been completed elsewhere, such as in the *Bt* eggplant case, direct regulatory costs do not appear to be prohibitive given the size of the benefits, assuming the benefits can be captured by those commercializing the product. It appears that the bigger concern in the release of transgenic products is the risk of regulatory time delays at any stage in the process point, as the cost (in terms of foregone benefits) of a delay of even one year overshadows any direct regulatory costs.

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Chapter 11

Value of Environmental Benefits of *Bt* Eggplant in the Philippines

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Introduction

Farmers in the Philippines apply frequent and heavy doses of insecticides in futile attempts to manage fruit and shoot borer (EFSB) in eggplant. Many farmers spray their eggplant two or more times a week. Pesticide use is expensive and potentially damaging to human health and the environment. However, indiscriminate pesticide application allows the borer to become tolerant to the chemicals, and pesticides can contaminate ground water and food, create resistance in target populations, affect non-target organisms, and induce secondary pest outbreaks.

Heavy application of pesticides for EFSB control was one factor that motivated the Agricultural Biotechnology Support Program II (ABSPII) to develop and commercialize transgenic *Bt* eggplant for farmers in Asia. The adoption of *Bt* eggplant technology may provide important economic benefits (as discussed in Chapter 4), as well as reduce health and environmental risks associated with pesticide use. Although genetically modified (GM) crops spark controversy around the world, with GM crops opponents concerned about possible long-term negative ecological effects (Schutte, 2003), reduced pesticide application with *Bt* eggplant can bring a potentially significant health and environmental benefits (Huang et al., 2002), which should not be ignored.

The GM debate occurs in the political arena, placing pressure on regulatory agencies that must approve GM products before they can be released. Regulatory agencies require substantial information from researchers in the natural and, in some cases, the social sciences (Carter and Gruère, 2006). While much of the information is biological in nature, economists may help by providing *ex-ante* assessments of benefits and costs of specific GM technologies, especially if they can place a value on potential environmental and health changes in addition to direct economic benefits and costs.

This chapter uses a variety of techniques to measure the environmental and health value of *Bt* eggplant currently being developed in the Philippines. *Bt* eggplant can potentially increase producer profits while significantly reducing pesticide use. When the product is commercialized, Filipino farmers may receive direct health and environmental benefits from reduced pesticide use, and consumers may receive health benefits from reduced pesticide residue in eggplant.

Quantifying environmental and health benefits of GM crops is difficult because impacts are potentially both positive and negative. Evaluation is made even more difficult by the fact that many people have little or no information about GM technologies and thus may have no opinion about them. Rousu et al. (2007) explored this situation in an experimental setting in the United States and found that respondents who had different types of information placed different values on GM products. As might be expected, those who were asked to read a negative portrayal of GM prior to value elicitation placed a smaller value on GM products than others who were asked to read a positive portrayal of GM.

In addition, the uncertainty that surrounds all new products complicates impact assessment because the exact environmental and health consequences cannot be determined until the product is widely used. Scientists make predictions about effects based on laboratory experiments, but GM crop detractors' concerns usually center on long-term and widespread uses. They believe that the long-term effects will be more adverse than what researchers can simulate in the laboratory (Barton and Dracup, 2000).

Some environmental and health valuation studies in developing countries have used contingent valuation (CV) to generate values. With CV, a series of questions are asked of respondents in a survey designed to elicit information on what people would be willing to pay for improved health or environmental benefits that are not valued in the marketplace. Surveys are administered to a sample population and average values are extrapolated from the responses. This method can be useful but also has some theoretical and practical difficulties (Bateman et al., 2002). Hypothetical bias can be a problem because survey respondents do not actually have to pay the values they indicate. Instrument design can help minimize hypothetical bias but not eliminate it. Lack of understanding about what is being valued can also be a problem. This lack of information could increase hypothetical bias if relevant information is not given on the subject.

When benefits cannot be achieved and maximized without community-wide support, values may also depend on values of other community members. In the Philippines, for example, the adoption of *Bt* corn depended on a number of social factors that included the opinions of peers (Yorobe and Sumayao, 2004).

To address this set of issues, multiple methods were applied in this study to quantify potential health and environmental impacts of *Bt* eggplant in the Philippines. The study aimed to assess the potential value of health cost savings and environmental improvements resulting from reduced pesticide use when adopting the *Bt* technology, and to identify policy implications of these health and environmental effects. The methods employed included contingent valuation (CV), experimental economics (EE), application of a health cost (HC) equation, and calculation of an environmental impact quotient (EIQ).

Methodology

The economic assessment of health and environmental impacts of reduced pesticide use following the adoption of *Bt* eggplant was accomplished by estimating first, the impacts of *Bt* eggplant adoption on the risks caused by pesticides to various non-target species and second, society's willingness-to-pay to reduce these risks. Risks were assessed for various categories of health and the environment. CV, EE, and HC analyses were used as alternative methods for valuing risk reductions, while the EIQ was used to score risk reductions without valuing them.

The health and environmental categories were classified according to the type of non-target organisms affected, such as humans, birds, beneficial insects, and farm animals, and the consequences of pesticide use on each category were considered. Risks posed by individual pesticide active ingredients (a.i.) for each category depend on toxicity levels and exposure levels of the organisms to the toxic substance. The impact of the pesticide active ingredient was determined by combining risk estimates with dosage and concentration of active ingredient in the formulation.

To measure the benefits of *Bt* eggplant adoption, information on the level of adoption of the technology was needed. The degree and level of adoption of *Bt* eggplant were predicted using an econometric model and results from previous studies. The change in the degree of pesticide risk brought about by changes in pest management activities due to adoption of *Bt* eggplant was calculated and combined with estimates of society's willingness-to-pay (WTP) for the reduction in pesticide risks.

Pesticide Risk

The level of pesticide toxicity and exposure for each environmental category were assessed using the following method:

$$ES_{ij} = IS_j * (\%\ \text{a.i.}) * Rate_i$$

where:

ES_{ij} = eco-rating score for active ingredient i and environmental category j,
IS_j = risk score for environmental category j,
% a.i. = percent a.i. in the pesticide formulation, and
$Rate_i$ = application rate per hectare

The ecological rating or risk impact score was computed with and without the *Bt* eggplant technology. The difference in the risk impact scores represents the amount of risk avoided if the *Bt* eggplant technology is adopted. Data on risk scores for the pesticides for the various environmental categories were obtained from Cuyno (1999). Application rates were obtained from a survey of 100 farmers in the Philippines (see Appendix 1 for a copy of the questionnaire).

Willingness to Pay (WTP)

Contingent valuation method

There is no market price on society's WTP to reduce pesticide risk, but a hypothetical market can be established using either CV or EE. These procedures are used to elicit values from respondents who provide hypothetical values (with CV) or actual payments for the risk reduction (with EE). For the CV analysis, a closed-ended iterative bidding method was used to elicit eggplant farmers' WTP for a safer formulation of the pesticide they perceived to be effective in the control of EFSB. Four different formulations were offered, namely: 1) one that avoids human health risk; 2) one that prevents risk to farm animals; 3) one that avoids risk to birds; and 4) one that prevents risk to beneficial organisms. The farmers were told the actual price of the pesticide, and were asked whether they will be willing to pay a specified amount for a reduction in insecticide risk that was described. If the respondent answered affirmatively, the price was then raised by PhP50.00 (about USD1.00) and they were asked if they would be willing to pay for it at the higher price if it had the environmental benefits. If they answered *YES*, the price was again raised by PhP50.00, and the last price before they said *NO* represents the farmer's WTP for the product. The last value to which the farmer responded positively represented his/her WTP for the risk reduction, i.e., the value that eggplant farmers place on the benefit of improving environmental quality with reduced pesticide risk to various categories of the environment.

A total of 100 farmers participated in the bidding in four eggplant-growing provinces: Pangasinan, Nueva Ecija, Batangas and Quezon. Twenty five randomly selected farmers from each province were interviewed using a structured questionnaire. Information asked of the respondents included crop losses due to EFSB, pest management practices for EFSB, pesticide use and cost, perceived effects of chemicals on the environment, and their WTP to avoid the perceived risks of pesticide use.

Experimental economics technique

For the experimental economics technique, the Filipino farmers were contacted in four groups including one farmer cooperative. Four experiments were conducted with individuals in each group. A facilitator explained that the valuation exercise would ask them to place a value on the environmental and health benefits from *Bt* eggplant. They were told that three randomly selected subjects would be paid an endowment of PhP500 (approximately USD10) each, but that those subjects would have to pay back the amount they placed on the environmental benefits to *Bt* eggplant research. After the instructions were read and questions answered, a short video about a previously released GM crop, *Bt* corn, was shown to help them understand what they would be valuing. After the video, an extension specialist discussed *Bt* eggplant emphasizing that the technology used to create *Bt* eggplant was similar to the one for *Bt* corn, and also stated that the environmental and health impacts of *Bt* eggplant could be similar to those of *Bt* corn.

The facilitator then asked them to submit their valuation of the environmental and health benefits of *Bt* eggplant. After all values were collected, the facilitator read each value aloud keeping the respondents anonymous. The whole process was repeated and subjects were allowed to reconsider their responses and submit a new set of values. After the fourth and final round, three subjects were randomly selected and each was paid PhP500. The three subjects were then asked to donate the final values they submitted to support *Bt* eggplant research.

After completing the experiment, the facilitators discussed with the respondents why they bid particular values. Some voiced fears about GM products, but the general consensus was that the immediate environmental and health damage from pesticide spraying was of greater concern than the possibility of long-term negative effects from GM products. Thirty seven percent of the respondents reported being sick from pesticide spraying and 80 percent believed pesticides harmed the environment, but they also emphasized that their incomes were dependent on the success of their crops, especially "cash" vegetable crops like eggplant.

Estimating the Environmental Benefits of *Bt* Eggplant

The environmental benefits of adopting *Bt* eggplant were estimated by combining the eco-rating scores and the elicited values for WTP for improving the environment by reducing pesticide risk, with projections on adoption of the technology and estimates on the proportion of pesticide use on eggplant in the affected area. The result represents the monetary value due to *Bt* eggplant adoption from reducing the risk to the four environmental impact categories, i.e., human health, avian species, farm animals, and beneficial insects.

Health Cost Model

In addition to the above, a health cost model estimated by Dung and Dung (1999) was applied to project savings that farmers and pesticide applicators would have if *Bt* eggplant technology was adopted. The model is:

$$\begin{aligned}\text{Ln HC} &= 2.7 + 1.24 \ln(\text{Age}) - 0.02\ \text{Health} + 0.12\ \text{Smoke} \\ &\quad + 0.62\ \text{Drink} + 0.075 \ln(\text{Ins}) + 0.144 \ln(\text{Herb})\end{aligned}$$

where: Age is age of farmer-respondent, Health is the farmer's weight-over-height ratio, Smoke is (0 for non-smoker, 1 for smoker), Drink is (0 for non-drinker, 1 for drinker), Ins is insecticide a.i. rate of application, and Herb is herbicide a.i. rate of application. This model was patterned after those utilized by Huang et al. (2000), Pingali et al. (1994, 1995) and Rola and Pingali (1993). Data in our study were obtained from the 100 farmer survey mentioned above.

Environmental Impact Quotient (EIQ)

A common way to present changes in pesticide use with GM crops is in terms of the volume of pesticides applied with and without GM. That method provides a useful but rough indicator of environmental impact, as it does not account for toxicity differences in specific products used in GM versus conventional crop systems. As such, an environmental impact quotient (EIQ) can be used to provide an improved measure of the environmental impact of *Bt* eggplant. The EIQ provides an aggregate assessment of the environmental risks associated with the active ingredients of the specific pesticides used. This indicator, developed by Kovach et al. (1992), effectively integrates the various environmental impacts of individual pesticides into a single field value per hectare. It draws on toxicity and environmental exposure data related to individual products, as applicable to impacts on farm workers, consumers, and ecology, which are then given equal weights. EIQ provides a consistent and comprehensive measure of environmental impacts associated with pesticide use, albeit with arbitrary weights across environmental categories.

Following Kovach et al. (1992), the farm worker component is defined as the effect on applicator and pickers due to exposure on pesticides, and is formulated as $C * [(DT * 5) + (DT * P)]$. The consumer component is the sum of consumer exposure potential and potential ground water effects, $C * ((S + P) / 2) * SY) + (L)$. The ecological component considers effects on fish, birds, bees, and beneficial arthropods: $(F * R) + (D * ((S + P) / 2) * 3) + (Z * P * 3) + (B * P * 5)$.The EIQ is the average of these three components:

$$\mathrm{EIQ} = \{(C * [(DT * 5) + (DT * P)) + [C * ((S + P) / 2) * SY) + (L)] + [(F * R) + (D * ((S + P) / 2) * 3) + (Z * P * 3) + (B * P * 5)]\} / 3$$

where DT = dermal toxicity, C = chronic toxicity, SY = systemicity, F = fish toxicity, L = leaching potential, R = surface loss potential, D = bird toxicity, S = soil half-life, Z = bee toxicity, B = beneficial arthropod toxicity, and P = plant surface half-life.

The field rate EIQ is calculated as (EIQ x pesticide % active ingredient x pesticide rate used). The field rate EIQ can be used to compare the total environmental effects of the conventional and the *Bt* eggplant crop production system. While it has been criticized because it includes arbitrary weights in its formulas, especially across environmental categories, the EIQ has been widely applied as an environmental indicator of pesticide risk to health and the environment.

Information regarding potential adoption rate and reduction in pesticide use was obtained from Francisco (2006). Many of the data for calculating the EIQ were obtained from New York State Integrated Pest Management Program (NYSIPM) (http://www.nysipm.cornell.edu/publications/EIQ.html).

Results and Discussion

Farmers across the four interview sites applied pesticides against EFSB 42 times on average during the production season, with Quezon having the highest number of applications (Table 1). They applied an average of 65 li/ha, equivalent to 12 kg a.i./ha.

Many farmers are aware of the effects of pesticides on human health and the environment. For example, 89 percent of the farmers interviewed believe that pesticides have a negative effect on human health, 76 percent believe it harms beneficial insects, 62 percent believe it harms farm animals, and 30 percent on birds. Forty six percent of the farmers reported to have experienced ill effects after spraying chemical pesticides, including dizziness, nausea, shortness of breath, loose bowel movement, and itchiness.

Table 1. Frequency, volume, and active ingredients of pesticides applied by eggplant farmers

Location	Freq of spray (times per season)	Volume (liters)	Total a.i (kg)
Batangas	27.92	74.24	6.24
Pangasinan	31.08	42.13	10.14
Quezon	55.01	79.05	16.93
Nueva Ecija	52.28	62.96	14.47
All sites	41.56	65.63	11.94

When asked to rank the importance of the different impact categories presented to them, they were unanimous in ranking human health as the most important among the impact categories considered, followed by farm animals, beneficial insects, and birds.

Pesticide Impact Scores

Table 2 presents the risk scores IS_j for (risks posed by) individual pesticides used in eggplant production. Using these risk scores, the eco-rating scores of pesticides were computed. Table 3 summarizes the results for the different impact categories with and without *Bt* eggplant. The projected changes in ecological rating due to *Bt* eggplant are as follows: 19 percent for human health and farm animals, 21 percent for bird species, and 19 percent for beneficial insects.

Table 2. Risk scores (IS_j) of pesticides used in eggplant production

Active ingredient	Brand name	Environmental category			
		Human	Animals	Birds	Beneficial insects
Insecticide					
Betacypermethrin	Chix 2.5 EC	4	4	1	5
Carbaryl	Sevin WP 85	2	2	3	5
Carbofuran	Furadan	3	3	5	5
Cartap HCL	Super Cartap 50 SP	3	3	3	5
Cartap HCL	Padan 50 SP	3	3	3	5
Cartap HCL	Dimo 50 SP	3	3	3	5
Cartap HCL	Buenas 50 SP	3	3	3	5
Cartap HCL	Dimotrin	3	3	3	5
Cartap HCL	Ingam 50 SP	3	3	3	5
Chlorpyfiros + BPMC	Brodan 31.5 EC	3	3	5	5
Chlorpyrifos	Siga 300 EC	3	3	5	5
Chlorpyrifos	Lorsban 40 EC	3	3	5	5
Chlorpyrifos + Cyper	Nurelle D	3	3	5	5
Cypermethrin	Magnum 5 EC	4	4	1	5
Cypermethrin	Poker 5 EC	4	4	1	5
Cypermethrin	Hukom 5 EC	4	4	1	5
Cypermethrin	Cypex 50 EC	4	4	1	5
Cypermethrin	Lakas 5 EC	4	4	1	5
Cypermethrin	Magik 5% EC	4	4	1	5
Cypermethrin	Servwell TKO 50 SC	4	4	1	5
Cypermethrin	Cypermethrin 5 EC	4	4	1	5
Cypermethrin	Cymbush 5 EC	4	4	1	5
Deltamethrin	Decis 2.5 EC	4	4	3	5
Deltamethrin	Superquick 2.5 EC	4	4	3	5
Dimethoate	Perfekthion 40 EC	4	4	3	3
Fenvalerate	Legend 2.5 EC	3	3	1	5
Fipronil	Ascend 50 SC	3	3	3	1
Imidacloprid	Admire 5 WP	3	3	5	3
Imidacloprid	Confidor SL 100	3	3	5	3
Imidacloprid + Cyfluthrin	Provado Supra 050 EC	3	3	5	3

Active ingredient	**Brand name**	**Environmental category**			
		Human	**Animals**	**Birds**	**Beneficial insects**
Lambdacyhalothrin	Bida 2.5 EC	3	3	3	5
Lambdacyhalothrin	Karate 2.5 EC	3	3	3	5
Malathion	Malathion	4	4	3	5
Malathion	Malathion 57 EC	4	4	3	5
Malathion	Planters Malathion 57 EC	4	4	3	5
Methamidophos	Tamaron 600 SL	4	4	3	5
Methomyl	Lannate 40 SP	4	4	3	5
Profenofos	Selecron 500 EC	4	4	5	5
Profenofos	Kilabot 500 EC	4	4	5	5
Triazophos	Hercules 20 EC	3	3	3	3
Triazophos	Hostathion	3	3	3	3
Fungicide					
Copper Hydroxide	Funguran-Oh	3	3	3	3
Copper Oxychloride	Vitigran Blue 58 WP	3	3	3	3
Mancozeb	Dithane M-45 WP	3	3	3	5

Table 3. Amount and percent changes in eco-ratings due to *Bt* eggplant adoption

Impact category	**Type use**	**Eco-rating without *Bt* eggplant**	**Eco-rating with *Bt* eggplant**	**% Risk avoided**
Human health	Insecticides	1,013.66	456.15	19.02
	Fungicide	1,917.56	1,917.56	
Total		2,931.22	2,373.71	
Farm animals	Insecticides	1,013.66	456.15	19.02
	Fungicide	1,917.56	1,917.56	
Total		2,931.22	2,373.71	
Avian species	Insecticides	1,222.51	550.13	21.37
	Fungicide	1,924.56	1,924.56	
Total		3,147.07	2,474.69	
Beneficial insects	Insecticides	1,493.14	671.91	18.67
	Fungicide	2,904.74	2,904.74	
Total		4,397.74	3,576.65	

Farmers' Willingness to Pay (WTP)

Based on contingent valuation analysis

Table 4 summarizes the farmers' WTP for pesticide risk avoidance obtained using CV analysis. On average, farmers were willing to pay a higher price for a pesticide formulation that is safer to humans (PhP1,019/li), followed by those safer for farm animals (PhP945), beneficial insects (PhP894), and lastly birds (PhP867). These results are consistent with the ranking that farmers placed on the different impact categories.

Table 4. Farmer's WTP to avoid risk to the different environmental categories

Impact category	Insecticide actual price (PhP)	Std dev	Farmer's WTP (PhP)	Std dev	Difference
Human health	724	416	1,019	572	295
Farm animals	724	416	945	531	222
Beneficial insects	724	416	894	508	170
Avian species	724	416	867	493	144

To estimate the value of potential health and environmental benefits from *Bt* eggplant, the percentage change in risk avoided is converted to a monetary value by combining it with the farmers' WTP for risk avoidance. The estimated values of benefits, presented in Table 5, were multiplied by the assumed adoption rate to project the benefits derived from risk avoided for the different environmental categories. For example, the aggregate benefits for human health would be PhP2.49 million, while the combined projected benefits for farm animals, beneficial insects, and avian species would be about PhP6.8 million. These environmental benefits are only for the area where the eggplant is produced and assumes no change in the use of other pesticides.

Using experimental economics

Due to the hypothetical nature of the CV estimates, the willingness of Filipino eggplant farmers to pay for reduced pesticide risk to health and the environment was examined as well using the EE technique. Farmers were willing to donate more than PhP400 for research on *Bt* eggplant if it reduces health and environmental risks. No Filipino farmer submitted a zero value in all rounds of the experiment. The farmers increased the amount they would pay after seeing the bids of their neighbors. Unlike in the CV interviews, farmers actually had to pay what was bid and therefore the results were not subject to the bias of a hypothetical question. By the final round of the experiment, farmers were willing to pay more than PhP450 on average, which is about 38 percent lower than that found using the CV method, where the total WTP per farmer across the four environmental categories adds up to PhP726 (see Table 5).

Table 5. Projected health and environmental benefits of *Bt* eggplant per farmer[1]

Impact category	% Risk avoided	WTP (PhP)	Benefits per farmer (PhP)	Projected benefits (PhP)
Human health	19.02	1,019.15	193.84	2,492,229
Farm animals	19.02	945.25	176.51	2,269,414
Beneficial insects	21.37	893.69	190.94	2,454,943
Avian species	18.67	867.25	164.95	2,120,786

[1] Assumed adoption rate of 50% of total eggplant area and farm area = 0.7 ha

The nature of the groups seemed to affect the results as well in the EE application. The farmer cooperative group had already began to adopt *Bt* corn, and their values started high and remained so across rounds. Their first round average was 76 percent of their endowment of PhP500 and their final round average was 97 percent of the same. The cooperative group can be contrasted to a group whose members farm in an area that had rejected *Bt* corn. In the latter group, values began at 32 percent of their endowment but ended at 91 percent.

Health Cost

The health cost benefits of *Bt* eggplant for individual farmers were estimated using the coefficients of Dung and Dung's (1999) health cost function. The incremental health benefits were determined as the difference in health costs with and without *Bt* eggplant. The health cost of *Bt* eggplant adopters would be only PhP2,570 compared to PhP2,733 for conventional eggplant producers, a savings in health cost of PhP163 per farmer. With a 50 percent adoption rate for *Bt* eggplant, the aggregate estimated health cost savings in the local producing areas would be PhP2,095,714, slightly lower than those in Table 5 for the human health category (PhP163 versus PhP196, and PhP2,095,714 versus PhP2,492,229), but are of similar magnitude.

Environmental Impact Quotient (EIQ)

Table 6 presents the results of calculating the EIQ and the field rate EIQ using the EXTOXNET database for the different insecticides and fungicides, with details in Appendix Table A-1. The mean pesticide usage by the non-*Bt* eggplant farmers was estimated at 12 li/ha, while that of *Bt* adopters was 6.2 li/ha, a reduction of around 48 percent. The EIQ for farmers not using *Bt* eggplant was 245 per ha while that of farmers using *Bt* eggplant was 198 per ha, a reduction of 19.5 percent. This environmental improvement would be realized only if *Bt* eggplant is commercialized and adopted by the farmers and accepted by the consuming public.

Table 6. Reduction in pesticide use and EIQ associated with adopting *Bt* eggplant

	Without *Bt* eggplant	With *Bt* eggplant	Difference
Pesticide use (kg a.i./ha)	11.98	6.22	5.76
Field EIQ	245.59	197.75	47.84
% Change in pesticide use			48.08
% Change in EIQ			19.48

Conclusion

The adoption of *Bt* eggplant will result in using fewer, less toxic, and less persistent insecticides, hence leading to a decrease in negative impacts on human health and the environment. This chapter assessed and attempted to value the health and environmental impacts from adopting *Bt* eggplant in the Philippines. Several methods were applied including contingent valuation of risk avoidance, experimental economics valuation of willingness to pay for environmental benefits, a health cost function, and environmental impact quotient. The data used in this study primarily came from various sources including a survey of 100 eggplant farmers in four eggplant producing provinces, interviews with farmer groups, and secondary sources.

The farmer survey found that eggplant farmers apply pesticides 42 times on average during the production period at an average rate of more than 65 li/ha (or around 12 kg a.i./ha). Farmers spend 29 percent of the production cost (about PhP28,000/ha) on pesticides to control EFSB. Upon inquiry in this study, most farmers believe that pesticides have a negative effect on human health, beneficial insects, and farm animals, and were unanimous in ranking human health as the most important among the categories considered.

Combining the farmers' willingness to pay from the CV analysis and the percentage reduction in risk for the different environmental categories, the adoption of *Bt* eggplant should save about PhP2.5 million in health costs and PhP6.8 million in other environment categories (farm animals, beneficial insects and avian species) in the target area. Using the Dung and Dung (1999) method to value health cost, the projected savings in human health costs are PhP2.1 million, with a pesticide use decline of 48 percent.

Results from the experimental economics analysis suggest that Filipino farmers are willing to sacrifice immediate monetary gains for potential environmental benefits from GM products if those products are expected to reduce pesticide use. Their willingness to sacrifice for environmental and health benefits from GM research, although about 38 percent lower than the value found with CV analysis, was still a sizable PhP450 pesos per farmer.

With Filipino farmers appearing to be receptive to adopting *Bt* eggplant, the projected positive impacts on human health, together with the agronomic and direct economic benefits of *Bt* eggplant, reinforces the need for continued support for its development and commercialization. Combining this type of analysis with private benefit-cost analysis leads to a more complete valuation of the social costs and benefits that accrue to farmers, consumers and the environment from *Bt* eggplant production. Information on environmental and health benefits will thus be very important in helping the public overcome the stigma towards GM products.

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Appendix 1.

Environmental Impacts of *Bt* eggplant
ABSPII – ISAAA Funded Project

FARMER SURVEY QUESTIONNAIRE

Name: ____________________ Location: ____________________
Education: ____________________ Years in farming: ____________________
Age: ______ Height: ________ Weight: ________ Farm area: ____________________
Do you smoke? ____________________ Do you drink alcohol? ____________________
Yield per ha of eggplant last year? ________ Ave yield over the last five years? ________
Ave annual crop loss (%) due to EFSB last year? ________ Over the last 5 years? ________

Part 1. Pest Management Practices

1. How would you describe the severity of EFSB problem?
Negligible [ ] Moderate [ ] Extreme [ ]

2. How did you control EFSB? Please check if you practiced any of the following pest management strategies
Pesticide application [ ] Crop rotation [ ]
Use of resistant varieties [ ] Use of treated seeds [ ]
Use of beneficial insects [ ] Others: ____________________

3. Pesticides use, amount and frequency of application

Control method used	**Frequency (per cropping season)**	**Quantity applied**	**Area**	**Remarks (e.g., brand names)**
Insecticides				
Fungicides				
Others (specify)				

4. Production cost structure

Cost Component	Quantity	Frequency	Price per unit
Seeds/planting materials			
Fertilizer			
Pesticides			
Labor			
Other			
Total production cost			

5. How much did you spend on chemicals last season? ____________

6. What is the most widely used pesticide that you perceived to be most effective in the control of EFSB? ____________ Price per liter (kg) PhP ____________

7. What percentage of your total annual operating expenses is spent on pesticides? ____________ %

8. How many hours per week do you spend in the farm? ____________

9. In your opinion, do pesticides adversely affect the following categories?

Categories	Yes	No	Do Not Know
Human health			
Beneficial insects			
Birds			
Farm animals, dogs, cats			

10. Have you ever experienced being sick from pesticide application? Yes [ ] No [ ]
What exactly did you feel? ____________

____

11. How important to you are the following possible risks from the use of pesticides on your farm?

Possible risks	Very important	Somewhat important	Not important	Relative rank
Damage to human health from applying pesticides				
Harmful effects to birds				
Harmful effects to mammals, farm animals				
Toxicity to beneficial insects				

Part 2. Willingness-to-Pay Questions

We would like to ask you questions about pesticide choices you might make next year. Assume that next year you will be planting the same crop and that climatic and pest conditions will be the same as this year.

1. Suppose that a chemical company made a new formulation of *(specify the most familiar/commonly used insecticide based on answer to question no. 6)* ______________ that was very similar to this insecticide in all respects (especially efficacy) and the only difference is that this new formulation **does not cause human health problems**. If this new formulation costs P ______________ (*offer different prices higher than the price of stated insecticide in 50-peso increments*), will you buy this new formulation? ______________

(Note: as soon as the respondent says NO, indicate last price agreeable to respondent)

2. Suppose that a chemical company made a new formulation of *(specify the most familiar/commonly used insecticide based on answer to question no. 6)* ______________ that was very similar to this insecticide in all respects (especially efficacy) and the only difference is that this new formulation **does not kill the natural pest enemies or beneficial insects**. If this new formulation costs P ______________ (*offer different prices higher than the cost of stated insecticide in 50-peso increments*), will you buy this new formulation? __________

(Note: as soon as the respondent says NO, indicate last price agreeable to respondent)

3. Suppose that a chemical company made a new formulation of (*specify the most familiar/commonly used insecticide based on answer to question no. 6)* ______________ that was very similar to this insecticide in all respects (especially efficacy) and the only difference is that this new formulation **does not kill the birds** in this area. If this new formulation costs P ______________ (*offer different prices higher than the cost of stated insecticide in 50-peso increments*), will you buy this new formulation? ______________

(Note: as soon as the respondent says NO, indicate last price agreeable to respondent)

4. Suppose that a chemical company made a new formulation of (*specify the most familiar/commonly used insecticide based on answer to question no. 6)* ______________ that was very similar to this insecticide in all respects (especially efficacy) and the only difference is that this new formulation **does not kill the animals** in the farm including the dogs and cats. If this new formulation costs P ______________ (*offer different prices higher than the cost of stated insecticide in 50-peso increments*), will you buy this new formulation? ______________

(Note: as soon as the respondent says NO, indicate last price agreeable to respondent)

Table A-1. Environment impact quotient (EIQ) and field rate EIQ for current pesticides used in eggplant production in the Philippines

Pesticide	Brand name	EIQ	Rate (per ha)	Active ingredient	Beneficial insects
Insecticide					
Carbaryl	Sevin WP 85	35.80	14.08	0.85	382.51
Carbofuran	Furadan	50.67	96.00	0.05	126.16
Chlorpyrifos	Siga 300 EC	43.52	13.05	0.30	313.25
Chlorpyrifos	Lorsban 40 EC	43.52	25.00	0.40	435.17
Cypermethrin	Magnum 5 EC	30.67	18.00	0.05	18.94
Cypermethrin	Poker 5 EC	30.67	43.20	0.05	60.28
Cypermethrin	Hukom 5 EC	30.67	13.05	0.05	20.01
Cypermethrin	Cypex 50 EC	30.67	6.25	0.05	9.58
Cypermethrin	Lakas 5 EC	30.67	5.54	0.05	28.35
Cypermethrin	Magik 5% EC	30.67	4.00	0.05	7.41
Cypermethrin	Servwell TKO 50 SC	30.67	5.60	0.05	8.59
Cypermethrin	Cypermethrin 5 EC	30.67	36.00	0.05	55.20
Cypermethrin	Cymbush 5 EC	30.67	2.64	0.50	40.48
Dimethoate	Perfekthion 40 EC	73.97	4.00	0.40	118.35
Fenvalerate	Legend 2.5 EC	49.58	4.00	0.03	4.96
Fipronil	Ascend 50 SC	90.92	9.60	0.05	93.33
Imidacloprid	Admire 5 WP	34.91	5.40	0.05	7.75
Imidacloprid	Confidor SL 100	34.91	0.40	0.10	4.91
Lambdacyhalothrin	Karate 2.5 EC	43.53	145.00	0.03	40.69
Lambdacyhalothrin	Bida 2.5 EC	43.53	8.40	0.03	9.14
Malathion	Malathion	23.83	25.20	0.57	94.69
Malathion	Malathion 57 EC	23.83	10.00	0.57	199.48
Malathion	Planters Malathion 57 EC	23.83	12.00	0.57	257.93
Methamidophos	Tamaron 600 SL	36.83	1.92	0.60	195.11
Methomyl	Lannate 40 SP	30.67	14.77	0.40	125.42
Fungicide					
Copper Hydroxide	Funguran-Oh	40.08	6.00	0.77	231.48
Mancozeb	Dithane M-45 Neotec WP	15.77	0.60	0.80	47.09

Chapter 12

Summary and Conclusions

G.W. Norton and D.M. Hautea

Substantial economic benefits are projected for research and development activities that have been undertaken for the purpose of commercializing bioengineered or GM products to solve major insect and disease problems in the Philippines and Indonesia. The economic impacts of transgenic papaya ringspot virus (PRSV) resistant papaya, insect resistant (*Bt*) eggplant, and multiple virus resistant (MVR) tomato in the Philippines, and late blight resistant (LBR) potato, insect resistant (*Bt*) potato, and MVR tomato in Indonesia are summarized in Table 1, for the most likely scenario recognizing that the results in the chapters illustrate a wide range of estimated benefits for each product depending on particular assumptions on elasticities, type of market, adoption rates, yield changes and so forth. Costs and benefits are projected over 15 years and discounted at 5 percent to obtain a net present value for each bioengineered product and country.

Under the base assumptions, the largest projected benefits are for PRSV-resistant papaya in the Philippines and late blight resistant potato in Indonesia (Table 1). The sum of discounted benefits, under the most likely scenario for each crop ranged from USD18 million for MVR tomato in Indonesia to USD216 million for PRSV resistant papaya. All of the bioengineered products are projected to earn high returns that justify the investments in their research and commercialization.

Table 1. Projected impacts of bioengineered crops in the Philippines and Indonesia over 15 years

Book Chapter	Product	Country	Net present value (million USD)
3	PRSV-R papaya	Philippines	216
4	*Bt* eggplant	Philippines	35
5	MVR tomato	Philippines	62
7	LBR potato	Indonesia	142
8	*Bt* Potato	Indonesia	48
6	MVR tomato	Indonesia	18

A look at some of the key assumptions in Table 2 for each product reveals why certain products ranked higher than others. The primary reasons for papaya ranking high are high yield change, adoption rate, and probability of success. LBR potato also ranked high because of its large production. The small projected yield change from adopting *Bt* potato and the low price for tomatoes in Indonesia appear to have reduced the benefits for these commodities. While they resulted in ranges of estimates, the sensitivity analyses confirm that these bioengineered products are profitable social investments and that PRSV-resistant papaya, the product that is expected to come to the market in the very near future, has the highest benefit.

Table 2. Key parameters for the most likely scenario

	Philippines			Indonesia		
	PRSV-R papaya	*Bt* egg-plant	MVR tomato	LBR potato	*Bt* potato	MVR tomato
Supply elasticity	0.8	0.5	0.75	1.0	1.0	1.0
Yield increase (%)	74	40	67	32	5	56
Cost change (%)	8	(16)	(10)	(13)	(25)	(8)
Probability of success (%)	83	73	74	50	50	50
Maximum adoption rate (%)	80	50	70	40	40	40
Discount rate (%)	5	5	5	5	5	5
Quantity ('000 t)	159	183	153	1,060	1,048	339
Product price (USD/ton)	363	200	215	225	394	120

The two chapters on papaya in this book illustrate that benefits for that crop are also sensitive to the assumption made about the extent of international trade for Philippine papaya as well as to the discount rate applied. A 5 percent discount rate is more realistic than a 10 percent rate and hence 5 percent was used in the base analysis throughout. However, Chapter 3 shows that PRSV-resistant papaya might struggle in international markets, in which case the benefits are reduced significantly from USD216 million to USD76 million (Chapter 9) (assuming the 1USD = PhP54 exchange rate at the time of data collection).

The results in Chapters 9 and 10 highlight the importance of moving products to the commercialization stage as rapidly as possible. The benefits foregone due to a delay of just a year or two far outweigh the direct research and regulatory costs. The same results are likely to hold in Indonesia even though the regulatory cost analysis was not completed in this study.

Projected Impacts of AGRICULTURAL BIOTECHNOLOGIES for FRUITS & VEGETABLES in the PHILIPPINES & INDONESIA

The book presents the results of a series of studies that assessed the potential economic impacts of bioengineered eggplant, papaya, and tomato in the Philippines and potato and tomato in Indonesia. Research and development (R&D) activities on biotech crops have been undertaken for the past years under the auspices of the Agricultural Biotechnology Support Project II (ABSPII) for the purpose of commercializing products that solve major pest problems in the target commodities and countries. This book summarizes the projected level and distribution of costs and benefits associated with these biotech crops, including the value of environmental impacts. R&D and regulatory costs are also quantified and highlights the importance of moving products to commercialization stage as rapidly as possible.

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