An Ex-Ante Economic Impact Assessment of Bt Eggplant in Bangladesh, the Philippines and India

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(ABSTRACT)

This study projects the economic impact of adoption of Bt eggplant in India, Bangladesh and the Philippines. The welfare benefits from adoption of Bt eggplant are projected to be positive in all three countries. The welfare gains from adoption (discounted at 5 percent) are projected to be US $ 411 million for India, US $ 37 million for Bangladesh and US$ 28 million for the Philippines. Consumers gain about 57% of the welfare benefits, while the producers gain 43% of the total surplus. Simulation results indicate that India is in a position to make significant investments in the development and diffusion of the Bt eggplant technology, while the Philippines and Bangladesh are likely to benefit from the transfer and adoption of technology from India. The simulations assumed a low seed premium, which would help in increasing the rate of adoption of the technology by the farmers. The findings suggest that potential economic benefits from Bt eggplant are high and efforts should be continued to develop and integrate the Bt eggplant with other IPM practices for effective pest management.

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CHAPTER 1. INTRODUCTION

Vegetables are an important source of nutrients (vitamins, minerals) for humans, especially in developing countries, where nutrient supplements are beyond the reach of the ordinary consumers. Vegetables provide dietary fiber to improve digestion and health, and they are essential for properly balanced diets. Thus, vegetables are a critical, irreplaceable dietary component that can prevent nutrient deficiency and produce healthy population. Vegetables can also easily fit into different cropping systems under diverse agro-ecological conditions. Vegetables are an important part of diets for people living in heavily populated Asian countries such as India, Bangladesh and the Philippines. Eggplant (*solanum melongena*) is an important vegetable grown in these countries (Rubatzjky and Yamaguchi, 1997).

Vegetable crops are very susceptible to insects and diseases. Fruits and vegetables use about seven times more pesticides than other crops (Fernandez- Cornejo, 1994). Eggplant fruit and shoot borer *(Leucinodes orbonalis*) is a major pest in South and Southeast Asian countries and is responsible for heavy losses, which can be as high as 90%. Its larvae feed from inside the fruit, making it unmarketable.

As eggplant is highly susceptible to insect pests, especially fruit and shoot borer, it receives a high number of insecticide sprays (sometimes as many as 20 to 30 per season). Also, a number of insecticides sold in developing countries including Bangladesh are extremely hazardous categories I and II chemicals (Pingali and Roger, 1995). Indiscriminate use of pesticides can lead to a number of problems such as health risk to the consumer, environmental pollution, and development of resistance in the insect pest against the insecticides. It can also lead to losses or low returns to the farmers because of the high cost of pesticide application.

1.1. Problem statement

Bangladesh is a densely populated country with an economy that is largely dependent on agriculture. It is estimated that agriculture contributes about 30% of its GDP while employing about 65 % of the labor force. Most of the farmers are illiterate with small fragmented landholdings. The small-holdings have led to extensive use of fertilizers and pesticides in an effort to boost production. Still, it is estimated that pests and diseases damage around 10-15% of the crops annually (Islam, 2002).

Pesticide use was fully subsidized in Bangladesh until 1974, when subsidies were reduced by half. They were completely withdrawn in 1979 leading to a decrease in the pesticide use. In Bangladesh, insecticides account for about 80% of all pesticides used, and were valued at around 535 million takas in 1997-98 (BBS & Plant Protection, DAE). (1 US dollar = 57.45 Taka). Heavy insecticide use results in high production costs for small farmers, thereby affecting their profit margins as it has been estimated that some farmers spend about 30 percent of their production costs on chemical pesticides. Despite pesticide use, there has been a decline in the yield of eggplant over the years in Bangladesh with the average yield dropping from 7.0 metric ton/ha in the early 1970’s to about 5.5 metric ton/ha in the late 1990’s (Bangladesh Bureau of Statistics). The per capita consumption of vegetables in Bangladesh is only around 183gm/day against the dietary requirement of 280gm/day. Bangladesh has a lower average yield than either India or the Philippines (Table.1.1), and there is a tremendous potential for increase in production of eggplant in Bangladesh with proper management practices.

Table 1.1 Eggplant Production Statistics for India, Bangladesh and Philippines

	Area (000' Ha)	Yield (Mt/Ha)	Production (000'Mt)
INDIA	450	14	6300
BANGLADESH	66	5	403
PHILIPPINES	17	9	159

source: FAO STAT Database

India is the largest producer of fruits and the second largest producer of vegetables in the world after China. The vegetables are cultivated in an area of 61 million hectares, with the total production of vegetables estimated around 81 million tonnes (1996-97). Eggplant is one of the important vegetables grown in India. In 2000, eggplant was cultivated on 460,000 hectares, with a production of 6400,000 tonnes. In spite of high production, the per capita consumption of vegetables in India falls below dietary requirements, as an average Indian diet includes only 140 grams of vegetables daily against the recommendation of 280 grams by ICMR (Indian Council of Medical Research). Insect pests including fruit and shoot borer are responsible for causing extensive damage to vegetable crops, but Integrated Pest Management (IPM) strategies may provide an economical and environmental friendly measure to control insect pests.

In the Philippines the contribution of agriculture to the GDP is about 20%. Eggplant is one of the leading vegetables in the country in terms of area and volume of production. In the Philippines, cultivation of eggplant has increased from 16,425 ha in 1990 to 17,797 ha in 1999, with a total production of 182,000 metric ton in 1999. The average yield has also increased from 7mt/ha in 1990 to 10 mt/ha in 1999. Fruit and shoot borer is one of the major pests of eggplant in the Philippines and is responsible for 20-92% damage (Bajet et. al, 2001). To control this pest, farmers make heavy use of chemical pesticides. In some cases farmers use higher than recommended dosage and also use chemicals that are not recommended.

Such indiscriminate use of pesticides is also causing health problems for farmers, as research findings have revealed that farmers spraying pesticides often suffer from heart and skin diseases, while cattle and goats are affected by consuming pesticide affected grasses (Alam,, 1981). Fish can also be affected by pollution in the rivers and lakes. A survey by the Bangladesh – Canada Agriculture Sector (Islam, 2002) showed that:

(i) 80% of farmers in Bangladesh know only about chemical control methods for insect and pests and are unaware of other methods.

(ii) Only 4% of dealers have adequate knowledge of pesticide doses and timing for different crops.

(iii) Most farmers believe that all insects are harmful and should be destroyed and are unable to differentiate between harmful and beneficial insects.

It is estimated that a large proportion of the pesticides applied (about 85%) do not reach their target, but gets dispersed into the environment, posing serious health risks to human and animals. The United Nations Environmental Program estimates that 5 million cases of pesticide poisoning occur globally every year (Islam, 2002). Repeated and indiscriminate use of pesticides can also lead to an outbreak of secondary pests by killing natural predators, which keep pest populations under control.

1.2. Integrated Pest Management:

For sustainable agriculture in Asia, IPM strategies are required to improve the production of eggplant and other vegetables, and to safeguard the environment. The Office of Technology Assessment (OTA 1979, 1:14) has defined IPM as "the optimization of pest control in an economically and ecologically sound manner, accomplished by the coordinated use of multiple tactics to assure stable crop production and to maintain pest damage below the economic injury level while minimizing hazards to humans, plants, and the environment."

The USDA has defined IPM as: "a management approach that encourages natural control of pest populations by anticipating pest problems and preventing pests from reaching economically damaging levels. All appropriate techniques are used such as enhancing natural enemies, planting pest-resistant crops, adapting cultural management, and using pesticides judiciously" (USDA, Agricultural Research Service 1993).

Kogan (1998) defined IPM as: " a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society and the environment."

IPM programs are specific to regions and crops just as pest problems are location specific. According to Fernandez-Cornejo (1996) a farmer can be considered to have adopted IPM if the farmer uses:

(i) Both scouting and economic thresholds in making insecticide application decisions.

(ii) One or more of additional insect management practices among those considered being IPM techniques.

Scouting is defined as: "The regular and systematic sampling of the fields to estimate pest infestation levels and subsequently determine if an economic threshold is reached" (Vandeman et al., 1994). Economic threshold is defined as: "The pest density (or amount of plant damage) at which the marginal cost of control just equals the marginal revenue of the crop. It is also called action threshold, control threshold, or treatment threshold" (Botrell, 1979).

Many IPM programs were initiated around the world in the 1970s. The first major IPM project in the USA, called the Huffaker project, covered seven crops, i.e. alfalfa, citrus, cotton, pines, pome, stone fruits and soybean during the year 1972-78. It was followed by CIPM, the Consortium for Integrated Pest Management during 1979-85 focusing on alfalfa, apple, cotton and soybean (Dhaliwal & Arora, 2001).

The Integrated Pest Management Collaborative Research Support Program (IPM-CRSP), a global research, training and information exchange program funded by USAID (United States Agency for International Development) and managed by Virginia Tech began in 1993. It aims to develop and implement new IPM technologies for different crops and is currently operating in nine countries: Bangladesh, the Philippines, Albania, Jamaica, Ecuador, Guatemala, Honduras, Mali and Uganda.

This program mainly focuses on developing suitable IPM technologies for vegetables, which are:

- environment friendly
- leave minimal residues
- help in lowering cost of production

One of the approaches used in IPM is to develop pest and disease resistant transgenic cultivars by introducing into the host plant a gene from *Bacillus thuringiensis* (Bt) that has insecticidal properties. A number of eggplant varieties have been identified, which show some resistance to fruit and shoot borer under the IPM-CRSP in Bangladesh and the Philippines. Scientists are working in Tamil Nadu in India under the IPM-CRSP project and other research projects to transfer the Bt gene to the preferred eggplant varieties. Field-testing of Bt eggplant started in June. It is predicted that the commercial varieties will be ready for release to the farmers in about 4 years. Scientists from Bangladesh and the Philippines will undergo training in India and will carry the gene constructs to their own countries to develop Bt eggplant using the indigenous varieties. Private seed companies in India are also working on developing a Bt eggplant variety as they estimate that the demand for such a variety would be high.

In Bangladesh, varietal screening experiments have been conducted by BARI (Bangladesh Agricultural Research Institute) to identify eggplant varieties that are resistant to fruit and shoot borer and bacterial wilt. Among 51 varieties tested, 5 were highly resistant (0 to 0.07% infestation), while 3 were resistant (3.9 to 8.4% infestation); also, 10 of the 81 eggplant varieties showed resistance to bacterial wilt (Rashid *et al.*, 2001). These varieties have the potential to be used by the farmers to produce eggplant without any pesticide use if they are acceptable in the market. Bacterial wilt (BW) is also a serious problem for eggplant cultivation in Bangladesh. A technique for grafting the commercial eggplant varieties onto BW- resistant eggplant rootstocks has been developed as an alternative to pesticides for this problem.

Experiments at BARI have shown that an average grafting success rate for eggplants of around 91% and with zero mortality of the grafts. In experimental conditions, the grafted eggplant varieties have produced about 40-63% higher yields than non-grafted ones (Rashid *et al.*, 2001). It was also reported that farmers were very much interested in using this technique on their farms. Research was also conducted to develop hybrids by crossing the resistant eggplant varieties with some of the selected commercial varieties.

The use of these technologies by farmers is affected by the lack of understanding of IPM practices by traditional farmers (IPM-CRSP baseline surveys in the Philippines and Bangladesh), as shown by the IPM-CRSP baseline surveys. A number of econometric studies have addressed the factors influencing IPM adoption. Some of these factors, among others, that had a significant influence on IPM adoption in previous studies were:

(i) Farm size: Larger farms are likely to adopt IPM before smaller farms (Fernandez-Cornejo, 1994).
(ii) IPM adopters were generally more educated and younger than other farmer. (Fernandez-Cornejo, 1994).

The Bt eggplant currently being developed is likely to provide effective resistance against fruit and shoot borer (*upto 90%)* and thus help in decreasing the usage of chemical pesticides. The Bt eggplant can also be grafted with other varieties (resistant to bacterial wilt) to provide protection against the bacterial wilt disease (*though it may need further research*).

The farmers are likely to adopt the new technology if they gain from the increase in yield and the decrease in the input costs resulting from the decrease in the number of sprays required for controlling fruit and shoot borer. Scientists predict that at most 2-3 sprays may be required for Bt eggplant to control fruit and shoot borer and other insect pests as compared to the current practice of more than 15 sprays per season.

1.3. Objectives

This study will focus on the ex-ante economic impact assessment of Bt eggplant in Bangladesh, India and the Philippines. The objective is to estimate the change in total economic benefits from the introduction of Bt eggplant in India, Bangladesh and the Philippines and its distribution among producers and consumers.

1.4. Research Hypotheses

(I) Adoption of Bt eggplant is cost effective and provides higher returns than conventional methods such as chemical pesticides.

(II) Adoption of Bt eggplant will result in welfare benefits to both producers and consumers.

1.5. Methodology

The aggregate welfare benefits from adoption of Bt eggplant in Bangladesh, India and the Philippines will be projected using a combination of ex-ante and ex-post economic surplus analysis. Ex-ante studies are helpful in allocation of funds for competing research projects by providing an estimate of payoffs or returns under different scenarios. Ex-ante studies depend on projections made by researchers, extension workers and social scientists regarding yield, success rate and the adoption of the new technology. Ex-post studies are more helpful in evaluating the accomplishments of a completed research project and for justification of future investment or continuation of the project. Sensitivity analysis is helpful in providing an estimate of welfare gains under different scenarios.

Secondary data regarding the market (price, demand, supply) are required for the analysis, which can be obtained from statistical organizations (Bangladesh Bureau of Statistics, Philippines Bureau of Statistics, FAO yearbook etc.) Data are also available from the ongoing field experiments in the two countries, which are used to obtain estimates regarding yield and input cost changes from adopting Bt eggplant, and the cost of the research etc. Previous studies in this area will also be used to obtain estimates of supply and demand elasticities.

1.6. Organization of the Thesis

A review of literature is presented in chapter II, which discusses previous studies in the economic impact of IPM programs and the method used for economic surplus analysis. The methodology for the research is discussed in chapter III. Chapter IV presents the results of the study and its implications for Bangladesh, the Philippines and India. Finally the summary of the results and the conclusions drawn from this study are presented in chapter V.

CHAPTER 2. LITERATURE REVIEW

It is important that any IPM strategy prove profitable to farmers to provide incentive for adoption. The most common method of estimating returns or welfare gains from an agricultural research project is partial-equilibrium economic surplus analysis (Alston et al. 1995). Norton et al. (1987) used an ex-ante framework to estimate potential benefits of an agricultural research and extension program in Peru. The study focused on five commodities and examined the effects of demand shifts over time and the influence of the government pricing policies on research benefits. Mills (1998) used an ex-ante framework to evaluate the potential impact of public sector maize research with and without trade barriers to external trade in Kenya. The study highlighted the importance of relaxing the trade barriers in order to benefit consumers by having lower prices, especially since population growth was predicted to cause difficulty in maintaining self-sufficiency in the future.

Pimental et al. (1992) estimated the environmental and social costs from pesticides in the United States and found that an expenditure of $ 4 billion on pesticides resulted in savings of about $ 16 billion in US crops but that there were environmental and social costs of around $ 8 billion each year. Thus, their study highlighted the fact that there are environmental costs associated with the use of chemical pesticides, which are not taken into consideration at the farm level. Norton and Mullen (1994) did a comprehensive review of literature on economic evaluations of IPM programs. Their study indicated that there was a decrease in the use of pesticides in all the studies except in the case of corn where there was an increase in pesticide use. There was a decrease or no change in the cost of production, while there was an increase in the yield and net returns in most of the crops.

Most of the studies that estimate benefits and costs of the IPM adoption have focused on the farm level impact using budgeting analysis (Norton and Mullen, 1994). There have been relatively few studies to estimate the aggregate economic impacts of

IPM programs or the environmental effects. Masud et al. (1981) examined the economic impact of IPM strategies for short-season cotton production in Coastal Bend Region of Texas. They found that IPM programs reduced per unit cost through reduction in pesticide use and by an increase in yields.

Rajotte et al. (1985) studied the economic returns from the soybean IPM program in Virginia and found that IPM techniques provided better returns than conventional methods, even when risk is considered. Daku (2002) studied the economic impact of olive pest management strategies under the IPM-CRSP project in Albania. The study indicated that adoption of IPM strategies resulted in higher yields and better quality of olives, though there was an increase in the production costs as a result of some IPM strategies.

Debass (2000) used partial budgeting and ex-ante economic surplus analysis to estimate the aggregate benefits of the IPM-CRSP strategies in Bangladesh and Uganda. The study showed that IPM strategies were more profitable than the current farmer practices of pest control in these countries and the welfare benefits were shared both by consumers and producers. Cuyno (1999) estimated the health and environmental benefits of the IPM-CRSP project in Philippines using a contingent valuation survey to estimate the farmer's willingness to pay to avoid risk from pesticide usage. The aggregate value of the environmental benefits was estimated to be US$ 150,000 for the villages under the IPM CRSP program.

The two major techniques used by economists to estimate the economic impacts of agricultural research programs are: the econometric method and the economic surplus method. Econometric methods are mostly used in ex-post studies where the effect of past investments in research can be estimated using data on inputs, outputs, and research expenditure. The economic surplus method is used in both ex-ante and ex-post studies and is one of the most commonly used methods to estimate the welfare impact of agricultural research (Davis, Oram, and Ryan, 1987).

2.1. Economic Surplus Method

The economic surplus method is used to estimate the returns from a research project by measuring the shift in the supply curve as a result of the research and the resulting increase in productivity (Norton et al. 1992). Such measurement requires estimates of (a) actual or expected changes in yield or reduction in cost (b) probability of success of the research program (if ex-ante), and (c) time frame for the research program and the adoption rate including depreciation rate (Norton et al.1992). The economic surplus method can be used to measure the change in the producer and the consumer surplus as a result of the program and the total (or net) welfare effect is the sum of the two (Fig. 2.1).

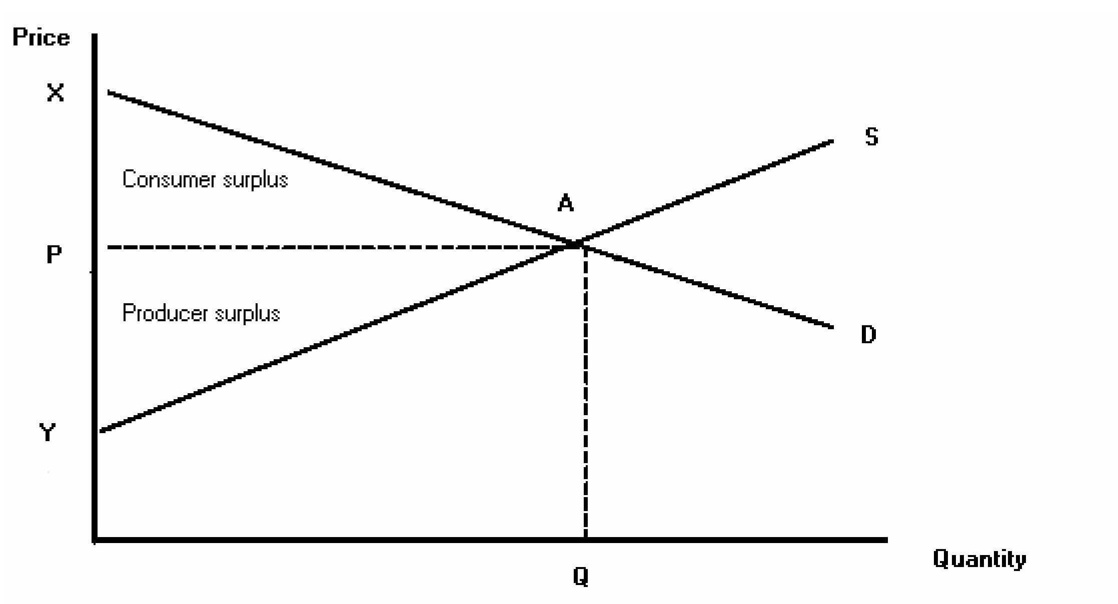

Fig 2.1. Consumer and Producer Surplus

In the figure 2.1 the area under the demand curve and above price P, represents the consumer surplus (area XAP), which is an amount the consumer is willing to pay but not charged for that good and hence is a saving in his expenditure. Similarly, the area above the supply curve and below the market price P represents the producer surplus (area YAP). The producer surplus is the net return to all the inputs in the production process by selling the output at the market price P. Marshall (1890) defined Consumer Surplus as: " The excess of the price the consumer would be willing to pay over the actual cost of the good. Producer Surplus has been defined by Mishan (1981) as: "The excess of the return to the factor owner above that necessary to induce him or her to provide the factor, and is analogous to consumer surplus."

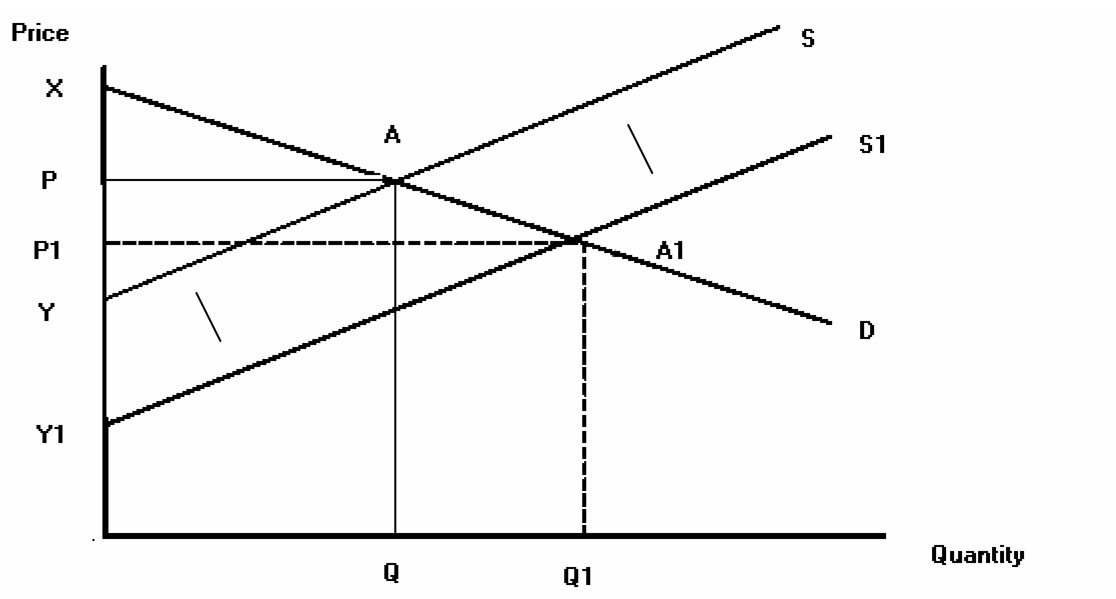

Fig 2.2. Effect of technological change on total surplus

The adoption of a new technology results in increased yield and/or a reduction in cost thereby increasing the supply and often reducing the equilibrium price, which is reflected in a downward shift of the supply curve (Fig. 2.2.). The net effect is that the per unit cost of production goes down, thus a new equilibrium price may be reached as the supply curve shifts downward and with a downward sloping demand the producers have to sell their output at a lower price. Consumers gain as they are able to buy more quantity of the product at a lower price, while producers are able to sell more but at a lower price. Producers gain if there is an increase in their revenue accompanied by a reduction in their costs. As a result of this, the total surplus, which is the sum of producer and consumer surplus, also changes. The area YAA_1Y_1 represents the change in total surplus.

After the changes in the total surplus are calculated or projected (for ex-ante studies), the benefit –cost analysis can be done by estimating the internal rate of return (IRR), net present value (NPV), or benefit-cost ratio. Estimation of economic surplus requires data on demand and supply elasticities and projections regarding the adoption pattern and the research lag. Estimates of yield, input costs and probabilities of success are obtained from the scientists working on the project.

However, there is some difference in opinion among economists regarding the nature of the supply shift ranging from a pivotal shift to a parallel shift. Norton et al. (1992) suggest using a vertically parallel shift for simplicity and consistency in evaluating the different programs for different commodities. It must be mentioned that total benefits from a parallel shift are almost twice those from a pivotal shift. According to Norton et al. (1992) producers always benefit from a parallel supply shift while they only benefit from a pivotal shift when demand is elastic. One of the most important parameters in the economic surplus analysis is the research induced proportionate shift in supply, also called **K** factor.

The formula for calculating the economic surplus depends on the nature of the market, i.e., if it is an open or closed economy, importing or exporting country, technology spillover in the region, etc. In this study, the closed economy model will be used as the exports or imports of eggplant in these countries are minimal and the domestic prices are not affected by the world price, as eggplant is a highly perishable commodity unlike food grains, which can be easily transported through sea. A very small quantity of eggplant is exported from Bangladesh for the Bangladeshi community living abroad, mainly the UK. One of the problems faced by exporters is the stringent quality and health regulations on pesticide residues for fruits and vegetables, which are imposed by importing countries. It is believed that adoption of IPM strategies may reduce the number of pesticide sprays and help in lowering the residue levels to acceptable standards.

The formula for calculating change in total surplus for a closed economy with linear demand and supply and a parallel research induced supply shift (Fig. 2.2) is as follows:

Change in Total Surplus (ΔTS) = Change in Consumer Surplus (ΔCS) + Change in Producer Surplus (ΔPS)

$\Delta CS = P_0Q_0\, Z\,(1+ 0.5Z\eta)$

$\Delta PS = P_0Q_0\,(K-Z)\,(1+ 0.5Z\eta)$

$\Delta TS= P_0Q_0\, K\,(1+ 0.5Z\eta)$

P_0 and Q_0 are initial equilibrium price and quantity, respectively

$Z = K\varepsilon/(\varepsilon+ \eta)$ relative reduction in price due to supply shift

ε = supply elasticity

η = demand elasticity

K= shift of the supply curve as a proportion of the initial price

Using the formula given by Norton et.al. (1995), the proportionate shift of the supply curve **K** can be calculated as:

$$K = \left(\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1+E(Y)} \right) p\ A_t\ (1\text{-}dt)$$

Where,

E(Y) = expected proportionate yield change per hectare from adoption of new technology

E(C) = expected proportionate change in variable input costs per hectare from adoption p = probability of success of achieving the expected yield change from adoption

A_t = adoption rate of technology in time t

d_t = rate of depreciation of the new technology

There has been some criticism of the economic surplus method because it ignores transaction costs[1], which results in overestimation of benefits from activities with high transaction costs. Alston *et al* (1995) have also pointed out that the partial equilibrium nature of the analysis ignores the effect of any relationship with other products and factors in the market and the issue of measurement errors associated with economic surplus analysis. Equivalent variation (EV), "the amount of additional money (income) that would leave the consumer in the new welfare position if it were possible to buy any quantity of the commodity at the old price", is more accurate than consumer surplus (CS) method as it also takes into account the income effect of the price change (Alston *et al*, 1995). But they further point out that errors associated with the assumptions regarding the demand and supply elasticities, nature of the supply shift, research lag and adoption, etc. are of greater magnitude than income effects or other shortcomings. They also mention that, given the limitations and constraints in evaluating the benefits of a research program, the partial equilibrium economic surplus model is one of the best and also one of the most commonly used methods to evaluate returns to research.

The economic surplus model can be modified to allow spillovers of technology and price across geographical areas and market distortions such as subsidies or taxes. The model can also be modified to disaggregate the benefits across different regions within a country though it is difficult to get accurate estimates for elasticities and price data for such an exercise.

[1] " Transaction costs are resource expenditures associated with information imperfections, the allocation and enforcement of property rights, and the 'frictions' of distance and time separating transactors. It may include personnel time, travel costs, communication costs, insurance costs, costs of product inspection services, costs of safeguarding property and in regulating trading practices." (Jaffee, 1999: 10-11)

CHAPTER 3. SIMULATION METHODOLGY

A closed economy model is used to simulate the economic benefits of adoption of Bt eggplant in India, Bangladesh and the Philippines. The total surplus change is given by the sum of the change in producer and consumer surplus. The supply curve is assumed to be linear and upward sloping, and the demand curve is assumed linear and downward sloping, and the research-induced supply shift is parallel (Fig.2.2).

The adoption of Bt eggplant will affect per unit cost of production, as there would be a decrease in usage of chemical pesticides and spraying costs. The adoption of Bt eggplant will also result in an increase in yield. Interviews of the scientists involved in the development of Bt eggplant indicated that it is possible that the benefits derived from the reduction in the input costs by way of decrease in pesticide usage could be higher than the gains through the increase in yield, although, it is not clear at this stage. Since, estimates for these data are not available as the technology is still in development stage, a range of possible scenarios were evaluated to account for the uncertainty. The model also assumed that since the Bt eggplant in India is being developed by the public sector the seed premium[2] are not likely to be very high (*though it is not certain at present*). The low seed premium would help in rapid adoption of the technology as the potential benefits from the adoption of Bt eggplant would be far greater than the initial investment required for the Bt eggplant seedlings, unlike the Bt crops developed by the private sector.

Farmers may readily adopt the new technology if it provides higher gains at a lower cost. The current problems[3] with the adoption of Bt cotton in some parts of India have been mainly because the seed premium for the Bt cotton have been very high (*about 5-6 times normal seed price*). If there is not enough returns from the adoption of a new

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[2] Seed premium is the additional price that the farmer has to pay above the cost of normal seed for hybrid or genetically modified crop seeds.

[3] Farmers reported low yield and income losses from Bt cotton in some parts of India last year because of drought.

technology due to any reason (improper management, drought etc.) then the rate of adoption in the following years is adversely affected. Low cost of entry helps avoid these problems, as the farmers perceive less risk in the adoption of the new technology. The development of Bt eggplant by the public sector is likely to keep the seed premium at a low level and thus helping in a rapid diffusion of the new technology.

The net welfare benefits from the adoption of Bt eggplant were discounted to their Present Value (NPV) using a discount rate of 5 percent[4] so that all the future gains can be compared on a common base. The internal rate of return (IRR), which is the interest rate that makes the present value of a cash flow (benefit stream) to zero, was also calculated for all the alternative scenarios of adoption. IRR and NPV are helpful in comparing the economic benefits of alternative projects and in decision-making. The excel spreadsheet model was used for the simulations as it allowed for the greater flexibility and simplicity in use. The formula used for NPV calculations is as follows;

$NPV = \sum (Bt/(1+r)^t)$, where Bt is the welfare benefits from the adoption in year t and r is the discount rate (5%).

3.1 Simulation of Bt eggplant adoption scenario

Since Bt eggplant is still not available and it is likely to take at least 4 years before it would be ready for commercial release in India and 6 years in Bangladesh and the Philippines, possible adoption scenarios are simulated to obtain an estimate of returns from the research project by calculating the total surplus, the net present value (NPV) and the internal rate of return (IRR). Estimates for the yield and input cost changes and adoption and research lags were obtained by interviewing the scientists involved in the development of Bt eggplant in India and the Philippines. Three scientists from India and

[4] 5% is considered to be the risk free real rate of return, which is the difference between the prime rate and the rate of inflation. For environmental projects social discount rate of 2% to 6% is generally used.

one from the Philippines working in the IPM-CRSP project for Bt eggplant were interviewed at Virginia Tech, USA.

3.1.1. Data Collection and Assumptions:

Data for own-price elasticity of demand and supply for eggplants were not available for India, Bangladesh and the Philippines, so estimates for elasticities of vegetables from previous studies conducted in these regions were used.

3.1.2. Demand elasticity:

Many economists have estimated the own-price elasticity of demand for vegetables in developed as well as developing countries. Most estimates for developing countries have been in the range of –0.5 to –0.75. Fan and Cramer (1994) estimated the food demand elasticities for rural China and reported the own-price elasticity of –0.54 for rice, -0.455 for wheat, -0.60 for meat, -0.47 for vegetables. They also found a positive price elasticity of demand for tobacco at 0.22, which implies that the consumption of tobacco in rural China increases even when its price increases. Huang and Lin (2000) estimated the demand elasticity for vegetables in the United States to be –0.74.

Ahmed and Shams (1994) estimated the demand elasticities in rural Bangladesh using AIDS (Almost Ideal Demand System) model. They found that the income effect of price changes were small for most commodities except rice, as other food items such as fruits and vegetables had very small shares in household expenditures. They found that about 69 percent of the total household expenditure in the sample was spent on food, out of which the share of rice was 44 percent compared to 4.5 percent for fruit and vegetables. The own-price elasticity of demand for fruits and vegetables was – 0.77. For this study, the own price elasticity of demand for eggplant in Bangladesh is set at – 0.77.

Similar studies have been done in the Philippines to estimate the price elasticities for selected food items. Ferre-Guldager (1977) estimated the own- price elasticity of demand of leafy vegetables in the Philippines as – 0.60 and fruit vegetables as – 0.75. Kunkel et al (1978) estimated the price elasticities of vegetables as – 0.78 in urban areas and – 0.71 in rural areas of the Philippines. Goldman and Ranade (1976) calculated the own price elasticity for vegetables in rural and urban areas to be – 0.67. For this study, the own- price elasticity of demand for eggplant in the Philippines is set at – 0.75. Similarly the own price elasticity of demand for eggplant in India is set at –0.77 as the demand for eggplant in India is likely to be similar to that in Bangladesh, with similar agricultural, socioeconomic structure, and food habits.

3.1.3. Supply elasticity:

Estimates of supply elasticities for eggplant in India, Bangladesh and the Philippines are not available. Rao (1989) estimated the agricultural supply response to prices in developing countries. He found crop specific acreage elasticities to vary from 0 to 0.8 in the short run and from 0.3 to 1.2 in the long run. He also mentions that the acreage elasticities are higher and more stable than the yield elasticities as the farmers can more easily control the acreage than the yield. Ahmed (1981) studied the supply response of rice to price change in Bangladesh. He found that a 10% increase in the price of rice raised the output by around 1.8 to 2.6%, where 50% of the increase resulted from an increase in area and the rest from increase in yield.

Mangahas et.al (1966) found that yield responses to relative crop prices in the Philippines were not statistically significant, while the acreage elasticities were significant. They further pointed out that, "price changes were not an effective device for influencing aggregate output……….at present levels of technology". Peterson (1979) used cross- country data from 53 countries to estimate a long-run supply elasticity, which ranged from 1.27 to 1.66. Chibber (1982) reported that cross-country supply estimates overestimated the price effect, as they do not control supply factors specific to a country. He used the same time series data as Peterson and found long run aggregate elasticity to vary from 0.29 to 0.46. Some studies have even estimated negative aggregate elasticities.

Yatopolous and Lau (1974) estimated a negative aggregate elasticity of output at –0.15 for Indian agriculture.

Binswanger et.al. (1987) suggested that individual crops have higher supply elasticity than aggregate output as the farmer can easily allocate his resources between different crops but his resources are more or less fixed for his total agricultural output. Askari and Cummins (1977) estimated supply elasticities for a number of individual crops for Chile, India, Thailand and the United States. They reported that the supply elasticity for minor crops is large as it is easier for the farmer to shift his resources to other crops. They also mentioned that the supply elasticity for a 'very important' crop such as rice in Thailand is also high as even small price changes can have a large overall effect on the farmer's income, while the supply elasticity for crops, which lie in between these two extremes (major crops), were very low. The other conditions, which were likely to result in a higher supply elasticity were: possibility of multiple cropping, irrigation facilities, availability of arable land, average income level of farmer and farm size (higher income increases ability to bear risks), and level of farmer education. For our study we will consider eggplant to be a minor crop as it is cultivated on less than 0.5% of total area under cultivation in Bangladesh where the most important crop is rice, which is cultivated on 72% of the total area. Similarly for the Philippines the figure is even lower, as hardly 0.01% of the total area under cultivation is devoted to eggplant. Thus, the supply elasticity of eggplant in both the countries is likely to be high.

Alston, Norton and Pardey (1995) suggest that long run elasticity for most single crops is greater than one and recommend using an elasticity of 1.0 for economic surplus analysis studies, if exact supply elasticities are not available. Since there are no exact supply elasticities for eggplant available for Bangladesh, India and the Philippines, the supply elasticity for eggplant for all the three countries is set at 1.0.

3.1.4. Adoption of Biotechnology:

It is important to make realistic assumptions regarding the adoption of new Bt eggplant in India, the Philippines and Bangladesh, as it is an important factor determining the magnitude of total surplus changes. Since Bt eggplant is still in the development stage, predictions regarding its adoption are made by interviewing scientists and by comparing the adoption rate of other Bt technologies such as Bt cotton in other countries. Adoption of the Bt eggplant is dependent on the success of the new technology in developing resistance against the fruit and shoot borer and also providing higher yields. Currently there are some cultivars available that provide resistance to insect pests but they are not high yielding. Researchers hope that by using biotechnology they will be able to develop a Bt eggplant that will not only provide effective resistance but will also be high yielding. For successful adoption of Bt eggplant it is important that the premium paid for such variety should be less than the total savings, which result from low or no use of chemical pesticides. However, there would also be gains as a result of increased yields. Since this Bt eggplant is being developed by the public sector, the seed premium for this variety is likely to be less as compared to the high price of seed for other Bt technologies like Bt cotton developed by Monsanto (private sector).

In a similar study Hareau (2001) assumed the highest level of seed mark up for transgenic potato to be equal to the cost reduction in pesticide use per hectare. Adoption of Bt technology has been quite extensive, especially in the United States where Bt cotton accounted for 17% of cotton acreage and Bt corn accounted for 19% of corn acreage in 1998 within three years of its approval by EPA in 1995 (Fernandez-Cornejo and Mc Bride, 2000). Pilcher et.al (2002) studied the adoption of Bt corn in the United States across several states over the period of three years. They found that adoption rates based on percentage of acreage planted to Bt corn (for farmers who were growing Bt corn) increased from 10.5% in 1996 to 40.7% in 1998. They reported that most farmers found the yields of Bt corn to be similar or higher than the non-Bt corn. It must be mentioned that the rate of adoption (diffusion) of Bt technologies and the ceiling (maximum) rate of adoption would vary from country to country based on various factors such as social perceptions towards transgenic crops, socioeconomic condition of the farmers, agro-ecological factors etc. This study assumes that the adoption path of Bt eggplant in India, Bangladesh, and the Philippines would be same with a research lag of 4 years in India and 5 years in Bangladesh and the Philippines. It is assumed that Bt eggplant would also follow the adoption path of other high yielding hybrid varieties in these countries since the farmers are not likely to have any negative perceptions towards Bt technology in India, Bangladesh and the Philippines. Swiss Federal Institute of Technology Zurich (ETH) carried out three surveys between 1997 and 2001 to study the public attitude and perceptions of agricultural biotechnology (genetically engineered food) in the Philippines and Mexico (Aerni, 2001). The survey focused on people who were likely to play an important role in the public debate over biotechnology and were familiar with the issue and its implications.

It included people from non-governmental organizations (NGO), farmers' organizations, government officials from departments of health, environment, trade, agriculture, and science and technology. The survey also included scientists from universities specializing in agronomy, environmental science and biotechnology and the members from agribusiness and food industry. Most of the respondents in both the Philippines and Mexico considered biotechnology as 'just a new tool' similar to other technologies, which are used to boost agricultural production over the levels achieved by conventional methods. They did not consider GM (genetically modified) food to be likely to cause any health risk to consumers, but they were concerned that it might affect the biological diversity if not used properly. Some Filipino respondents were worried about the possibility of the pest resistant Bt rice having a negative impact on other beneficial organisms in the field (Aerni, 1999). Respondents in the Philippines had adequate confidence in the bio-safety regulations in the country, unlike Mexican respondents who found their existing bio-safety regulations to be inadequate. Interestingly, it was found that respondents affiliated to agriculture and science technology or trade, were more likely to be in favor of agricultural biotechnology than the respondents from the

Department of Environment. There was some criticism of the survey and its results, as it did not include farmers who are the ultimate beneficiaries of these technologies and therefore the most important group. The researchers defended their view by arguing that the opinion of the farmers would be based on the general opinion of the representative group covered by the survey as this group was supposed to represent the interests of the farmers.

The survey highlighted the difference in public opinion towards biotechnology and GM foods in developed and developing countries. While there is a considerable opposition to GM foods in Europe by environmental groups such as Green Peace, people are more in favor of biotechnology as a means of boosting agricultural production and increase in farmers' income in developing countries. It must be stressed that the survey in the Philippines focused mainly on the adoption of Bt rice, which was developed by International Rice Research Institute (IRRI), but the scientists pointed out that the losses caused by stem borer in rice were only around 5 percent. Thus, the adoption of Bt rice did not result in any significant yield benefits in comparison to the perceived risks, which may result in some opposition to adoption of Bt rice in the Philippines.

In the case of Bt eggplant, the damage caused by fruit and shoot borer is more severe and the farmers are spraying more than 15-17 times in the growing season. Thus, farmers and consumers both are going to benefit from Bt technology by way of reduced cost of production and decreased pesticide residue problem, respectively. Researchers studying the adoption of IPM techniques by vegetable farmers in the Philippines found that farmers in the Cordilleras were able to reduce their pesticide expenditure from 60 million Pesos in 1991 to 20 million Pesos in 1994 with a significant increase in their yields (IFCS, 1996). Some green onion farmers in Canalon were able to reduce their pesticide expenditure by 91 percent with an 8 percent increase in yield and about 40 percent increase in their net income (IFCS, 1996). Ali and Hau (2001) studied the economic impact of new varieties and technologies of vegetables in Bangladesh and reported that the farmers who adopted the new technology decreased their use of pesticides. They reported that adoption of new technologies resulted in a 38 percent increase in average yield while per unit cost of production decreased by about 20 percent. The total economic surplus of the ten-year project was estimated at US $ 8.8 million with a producer surplus of US $ 4.6 million and a consumer surplus of US $ 4.2 million. The internal rate of return (IRR) from the investment of US $ 7.1 million by USAID and Government of Bangladesh over the nine-year project on vegetable research and development was calculated to be 42 percent.

There are no data regarding the adoption rate for transgenic vegetables in India, the Philippines and Bangladesh as they are not commercially available and are still in development stage so one might assume the adoption rate to be similar to the adoption rate of other high yielding varieties of crops. The adoption of high yielding varieties for five major crops (rice, wheat, maize, sorghum, and pearl millet) in India reached the level of about 60% in 1995 since their introduction in the 1970's (Zhang et.al., 2002). The annual growth rate of adoption was around 9% during the 1970's at the peak of the green revolution and decreased to about 2% in the 1990's (Zhang et.al.,2002). The adoption rate of transgenic crops such as Bt cotton has been rapid in China while it is still in the early stages of commercial release in India. Since the introduction of Bt cotton in China in 1997, it is now being grown in area of about 1.5 million hectares (2001), which is about 35% of the total area under cotton cultivation in China. The adoption of Bt eggplant is likely to be slower than Bt cotton as there are many different types and varieties of eggplant currently being grown to cater to different tastes and preferences of consumers especially in a country the size of India. It will take some time before suitable varieties for all the agro ecological zones are developed for release in India, Bangladesh and the Philippines. The issue of resistance management strategies for Bt technology such as growing of refuge in the periphery might also affect the rate of adoption of the technology.

Experiments conducted in China (Zhao, 1998) indicated that the Bt cotton might start to lose some of its resistance after about 6 years, although if careful management strategies are implemented such as growing other crops around the field or by growing non-Bt cotton in the periphery of the Bt cotton field the loss of resistance may be postponed further.

Zhao (1998) estimated the usefulness of Bt cotton to be around 10 years as it would lose most of its effectiveness after that because Bollworm would develop resistance to it. For our study we assume that the Bt eggplant will continue to provide benefits for a period of 15 years after which it will be replaced by another technology or variety. The adoption rate of Bt cotton in China has been very high (Table 3.1) and we expect that Bt eggplant will also follow a high rate of adoption in India, Bangladesh and the Philippines.

Table 3.1. Area under Bt Cotton in China

Year	Total Bt cotton (ha)	Total cotton area (ha)	Bt cotton (%)
1996	16,667	4,720,000	0.35
1997	34,000	4,490,000	0.76
1998	228,000	3,868,667	5.89
1999	578,000	3,169,333	18.24
2000	1,076,000	3,600,000	29.89
2001	est.1.4 - 1.8 million	est. 4,733,333	est. 29.6 - 38.0

Data source: Cui Jinjie, Cotton Research Institute of CAS

We assume that the maximum adoption rate for Bt eggplant in India, the Philippines and Bangladesh will be 35% for the base level, which will be reached 5 years after release. Sensitivity analysis will also be done to estimate the potential benefits at different levels of adoption. Mamaril (2002) used a linear annual adoption [5] rate of 6 percent for adoption of Bt rice in Philippines and a maximum adoption rate of 66 percent. This study assumes a linear annual adoption rate of 5 % for adoption of Bt eggplant; sensitivity analysis would also be done to find out how the adoption rate affects the

[5] The proportional increase in area planted to Bt eggplant per year

welfare benefits. The study assumes a linear trapezoidal adoption path with a research lag of 4 years for India and 6 years for Bangladesh and the Philippines (*as technology will be transferred from India*), linear adoption phase of 5 years, a plateau phase of 5 years, and a linear decline phase for 5 years (Fig. 3.1).

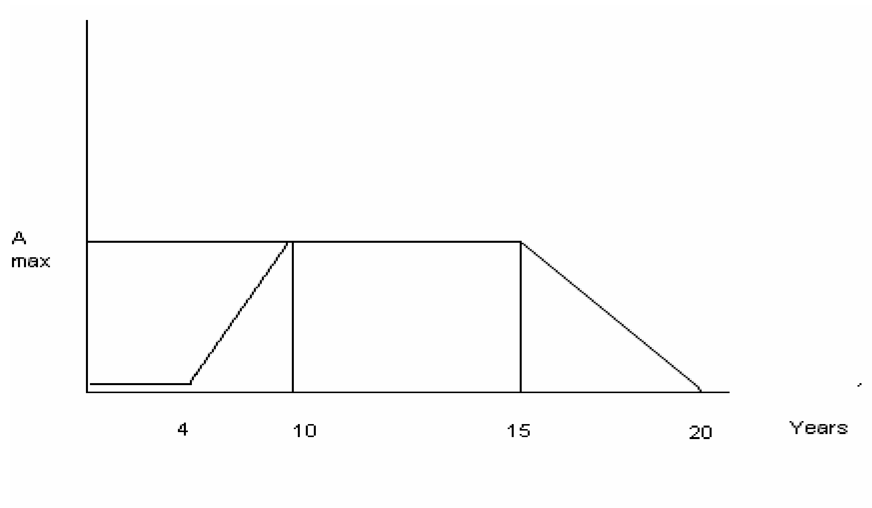

Fig. 3.1. Adoption Profile for Bt Eggplant

3.1.5. Change in Input cost and Yield:

As the technology is still in development stage reliable estimates of changes in input costs and yield from its adoption cannot be obtained. It is estimated that farmers in Bangladesh spend on average about 30 percent of their production cost of eggplant on chemical pesticides alone. If we include the cost of labor for spraying then the savings in input cost could be around 40%. Aganon et. al (1997) estimated the economic benefits of strategically timed application of pesticides as compared to farmers practice for eggplant and string beans in Philippines.

The results indicated that farmers spent about 30% of their production cost on insecticides and labor. The farmers sprayed about 13 times during the growing season as compared to about 7 strategically timed applications by the researchers. For Bt eggplant it is assumed that 2-3 sprays would still be required to protect from other insect pests, which are not targeted by the Bt toxin as transgenic plants rarely provide 100% control of the target pest but they help to retard insect attack (Estruch et.al., 1997). By interviewing the scientists working on the Bt eggplant it was known that the current variety being tested in India has only 75% resistance to fruit and shoot borer, but efforts are on to increase the level of resistance to 90%. This study assumes that there would be about 15% increase in yields from adoption of Bt eggplant[6] (*from the reduction in yield losses due to fruit and shoot borer*) in India, the Philippines and Bangladesh, and there will be about 30 % decrease in the production cost. The yield gain from adoption of transgenic crops varies from one country to another. Generally, yield gains from Bt technology are higher in developing countries as the farmers do not time the application of pesticides strategically, when they are more effective (Qaim, 2003). The yield increase for the base simulation is kept at a lower level (15%) but increase in yield from Bt eggplant could be upto 30% and the benefits from higher levels of yield increases are estimated in the sensitivity analysis.

3.1.6. Prices:

For the Philippines, the average wholesale price of eggplant for the period 1996-2000 is Peso 12400 per ton (DA- AMAS, 2001), which is equivalent to US $ 234 per ton (1 US dollar = 53 Peso). For Bangladesh, the average wholesale price of eggplant for 1996-1999 is 5830 Taka per ton (Bangladesh Bureau of Statistics, 1999), which is equivalent to US $ 97 (1 US Dollar = 60 Taka). The prices are held constant for 20 years for the simulation. For India, the average wholesale price of eggplant was calculated to be Rs. 4910 equivalent to US $ 104 (1 US dollar = 47 Rupees) using data from National Horticulture Board for the year 1999.

[6] The yield loss in eggplant due to fruit and shoot borer has been estimated to range from 25-90% in the Philippines (Bajet. et.al. ,2001)

3.1.7. Quantities:

The area under eggplant cultivation doubled in Bangladesh in the year 1999 to 66,390 hectares from 30,200 hectares in 1998. The area under cultivation averaged around 30,000 hectares over the period 1996-1998. One possible reason for this could be an increase of about 50% in the average market price of eggplant in 1998 over the price in 1997 leading to an increase in the planting of eggplant in 1998-1999. The average price increased further by about 12% in 1999. Since the increase in the area is very significant, only the latest figure for 1999 is considered in the study, as taking average would lower the figure considerably. Since the area under cultivation has not declined in the past it is believed that the upward trend would continue in the future. The total production of eggplant in Bangladesh was 403,000 tons in 1999 (BBS, 2001). The average total production for Bangladesh is thus set at 403,000 tons.

The area under eggplant cultivation in the Philippines has been relatively stable at around 18,000 hectares averaged over the period 1997-2000 (DA-AMAS, 2001). The average production of eggplant in the Philippines during 1997-2000 was 171,000 tons. The average total production of eggplant in the Philippines is set at 171,000 tons for the study. For both the countries, no exports and imports of eggplant are assumed and all the production is assume to be consumed domestically. Although there are some exports of eggplant from Bangladesh, they are small and not considered significant for the purpose of this study.

The area under eggplant cultivation in India has been increasing marginally over the period 1997-2000 (NHB, 2002). The average production in India over the period 1997-2000 is 6,250,000 tons and is set at this level for this study. The average yield in India has been stable at around 14 tons per hectare and is much higher than Bangladesh (6.1 tons/ha) and the Philippines (9.4tons/ha).

3.1.8. Other Variables:

Since Bt crops have been developed and commercialized and Bt eggplant has already been field tested in New Jersey, it is assumed that the probability of success of Bt eggplant in India, Bangladesh and the Philippines is 1.0. Sensitivity analysis will also be done with lower success rate to estimate its effect on the size of the welfare benefits. The Bt eggplant technology is assumed to depreciate linearly at the rate of 10% after 10 years or 6 years from its commercial release.

CHAPTER 4. RESULTS AND DISCUSSION

This chapter presents the results of the ex-ante simulation for the adoption of Bt eggplant in India, Bangladesh and the Philippines. First, the net benefits of the base scenario is presented and then alternative scenarios are calculated using different values for the expected yield and input cost changes as a result of adoption of the Bt eggplant. Since the technology is still in the development stage, reliable estimates for the yield and input cost changes are still not available and estimates for the likely changes were obtained by interviewing the scientists involved in the development of Bt eggplant. For an ex-ante study projecting the impact of a technology that has not been developed, it is important to simulate different scenarios to account for the uncertainty of the research program and results. The simulations assume a closed economy model for eggplant for India, Bangladesh and the Philippines. The base data used for the simulation are presented in Table 4.1.

Table 4.1 Base Data for simulation of economic benefits from Bt eggplant adoption

	India	Bangladesh	Philippines
Production (000' Mt)	6250	404	165
Area (000' Ha)	450	66.4	17
Yield (Mt/ha)	14	6	9.5
Price (US $/ton)	104	148	279
Price elasticity of demand	-0.77	-0.77	-0.75
Price elasticity of supply	1	1	1
Expected increase in yield	15%	15%	15%
Expected reduction in input costs	30%	30%	30%
Maximum adoption rate	35%	35%	35%
Research Lag (years)	4	6	6
Probability of success	100%	100%	100%
Depreciation (years)	10	10	10
Complete depreciation (years)	20	20	20
Research Cost (2002) US $	23,150	3,850	4,950
Research Cost (2003) US $	15,950	4,950	6,050

Simulations were completed for different assumed levels of yield and input cost changes for all three countries to account for the possible variations in the expected results from the adoption of the Bt eggplant. The Net Present Value (NPV) and the Internal Rate of Return (IRR) were calculated using the discount rate of 5.0% for all the scenarios to compare the effects of adoption under the different conditions for a period of 20 years. The research costs for the development of technology for the three countries were used for the period of 4 years for India and 6 years for the Philippines and Bangladesh. Since the budget estimates for the research project are available for only two years i.e., 2002 and 2003, the budget estimates for research beyond that were set at the level fixed for the year 2003. It should be noted that the research cost used for the simulation was only the budgeted cost for the research project funded by the USAID under the IPM-CRSP project for these sites. The salaries of the scientists involved in the research project have not been included as they are not a part of the project cost and they receive their salary from their respective organizations. The research project only provides for the salaries of the junior staff hired for the research project. The transfer of technology to the farmers and its commercialization will involve further investment but these costs will not affect the results of the simulations significantly as the economic benefits from the adoption of Bt eggplant are proportionately much higher than these investments. Thus, the actual benefits from the adoption of the Bt eggplant would be somewhat lower than the simulation results when all the costs are included in the model. Sensitivity analysis will also be done to estimate the effect of research costs on the size of the total welfare benefits.

The Bt eggplant currently being developed under the IPM-CRSP project in India is not a hybrid and thus the farmers may be able to use its seed next year, which is likely to help in the rapid adoption of the technology and would also keep the cost of the Bt eggplant seedlings low. The adoption of the Bt technology by the farmers is very much dependent on the possible economic benefits of the technology. The farmers are likely to benefit in two ways, first by an increase in marketable yield and secondly by a reduction in the input cost by minimal usage of chemical pesticides and spraying costs. Thus, even a conservative estimate of 15% increase in yield and 15% decrease in input costs is likely to result in significant savings for the farmers, provided the cost of adoption of this technology is low. Since this technology is being developed by the Government institutes, it is assumed that the government may also play a significant role in promotion of this technology, which would keep the costs low and boost its adoption for there is no profit motive unlike the hybrid Bt cotton currently being promoted in India by the Monsanto (Private Company). At this stage, the mechanisms for the commercialization of this technology have not been developed. The technology is still in the development stage and will have to tested by the bio-safety committees in respective countries before it can be released for commercialization. The base adoption scenario assumes an increase of 15% in the yield and a decrease of 30% in the input costs from Bt eggplant adoption (Table 4.1.).

Further simulations using the base data (Table 4.1) were completed for the expected increase in yield to be 30% and 45% and the expected decrease in input cost to be 15% and 45% to account for the uncertainty in the possible results and estimates. Thus, there were nine possible scenarios for these simulations to account for all the possibilities of yield and input cost changes. These simulations also give an idea about the effect of yield level and input cost changes on the total economic benefits from the adoption, as the actual adoption of the Bt eggplant by the farmers would also depend on these factors. These simulations were completed to estimate the aggregate benefits for the entire country, as region specific models were not developed. There may be some differences in the distribution of these benefits within the countries, with some states or regions benefiting more than others, as there are variations in yield and productivity within different regions of each country. The results of these simulations for India are presented in the table 4.2

Table 4.2.Simulation results of aggregate economic benefits to India under different conditions of yield and input cost change from Bt eggplant adoption

Expected Yield increase (%)	Expected decrease in input cost (%)	Net present Value (US $)
15	-15	278,579,970
	-30	410,744,687
	-45	544,536,796
30	-15	415,348,761
	-30	533,670,097
	-45	653,264,939
45	-15	557,076,114
	-30	664,464,435
	-45	772,876,407

The simulation results indicate that even with a conservative estimate of a 15% increase in yield and a 15% decrease in input cost, India would gain about US $ 279 million (NPV). The potential benefits from a 15% increase in yield and 30% decrease in input costs results in a potential benefit of US$ 411 million. If the expected increase in yield is 45%, with a 45% decrease in input costs, then the potential benefits for India would be around US $ 773 million. The simulation results indicate increases in yield and decreases in input costs have roughly the same impacts on the potential benefits. If there were significant additional costs involved in further developing and commercializing the Bt technology in India, the potential benefits would still far outweigh the additional investments required for the development and diffusion of the Bt eggplant. These simulations were conducted with the maximum adoption rate of 35%. If the technology is successful, the maximum adoption rate will be higher as eggplant is primarily a cash crop and farmers would readily adopt this technology if there were large economic gains from its adoption. Similarly simulations were run to estimate the potential benefits from the adoption of Bt eggplant in Bangladesh and the Philippines. Table 4.3 presents the simulation results for Bangladesh.

Table 4.3. Simulation results of aggregate economic benefits to Bangladesh from Bt eggplant adoption under different conditions of yield and input cost change

Expected increase in yield (%)	Expected decrease in input cost (%)	Net Present Value (US $)
15	-15	25,010,634
	-30	36,883,219
	-45	48,901,996
30	-15	37,296,811
	-30	47,925,821
	-45	58,669,233
45	-15	50,028,424
	-30	59,675,303
	-45	69,414,138

The simulation for the base level with a 15% increase in yield and a 30% decrease in input cost results in a potential benefit of US$ 37 million (NPV) to Bangladesh. A more conservative estimate of 15% increase in yield with only 15% decrease in input costs results in a potential benefit of US$ 25 million (NPV). The maximum potential benefit to Bangladesh under the assumption of a 45% increase in yield and a 45% decrease in input costs from the adoption of Bt eggplant is US$ 69 million (NPV). Thus, even with a 35% maximum adoption rate in Bangladesh, the minimum potential benefits from the adoption of Bt eggplant would be around US$ 25 million (NPV). In comparison to the investments required for the development and diffusion of the technology, the economic benefits are much higher. If we incorporate the cost of environmental benefits, which would result from the decrease in the usage of chemical pesticides, the potential benefits would be even higher. However, it is difficult to measure the environmental benefits in strictly economic terms without assigning an economic value to the environmental factors such as health hazards to human and animals from pesticide usage, ground water contamination, etc.

Table 4.4 presents the simulation results for the Philippines from adoption of Bt eggplant under different levels of yield and input cost change.

Table 4.4. Simulation results of aggregate economic benefits to the Philippines from Bt eggplant adoption under different conditions of yield and input cost change

Expected yield increase (%)	Expected decrease in input cost (%)	Net Present Value (US $)
15	-15	19,242,850
	-30	28,379,353
	-45	37,626,740
30	-15	28,697,602
	-30	36,875,719
	-45	45,140,609
45	-15	38,493,346
	-30	45,914,515
	-45	53,405,431

The simulation for the base level of 15% increase in yield and 30% decrease in input cost from adoption of Bt eggplant, results in a potential benefit of US $ 28 million (NPV) for the Philippines. The minimum potential benefits to the Philippines are US $ 19 million (NPV) when there is only 15 % increase in yield along with a 15% reduction in input costs. The maximum potential benefits to the Philippines are US $ 53 million (NPV) when there is a 45% increase in yield along with a 45% reduction in input costs.

In all the cases, consumers gain about 57% of the total surplus while the producers gain only 43% of the total surplus. The results of these simulations for all three countries indicate that even with a modest level of adoption of only 35%, all the countries are likely to gain, with the maximum gain in India followed by Bangladesh and the Philippines, respectively. In comparison to the potential benefits from the adoption of the Bt eggplant, the cost of further investment required for the development and commercialization of the technology is not very significant. It must be mentioned that the actual costs of the research project would be higher if we take into account the salary of all the scientists involved in the development and diffusion of this technology, but even then the benefits would far outweigh the costs. A sensitivity analysis would also be done with different levels of research costs to estimate its effect on the size of the welfare benefits.

4.1. Other Sensitivity Analyses:

Sensitivity analysis of the simulation results was also done to examine the effect of different levels of adoption rate, supply elasticity, research costs and the probability of success of the research project on the total surplus and to account for all possible scenarios of adoption of Bt eggplant in India, Bangladesh and the Philippines.

4.1.1. Adoption Rate:

The baseline scenario assumes a maximum adoption rate of 35% for Bt eggplant in all three countries. Since, the Bt technology is relatively new and there are other social issues involved in its adoption such as producer's and consumer's perception towards genetically modified plants, the adoption rates for other technologies in agriculture like hybrid vegetable varieties cannot be considered as reliable estimates for the likely adoption rate for Bt eggplant in India, Bangladesh and the Philippines. To account for this uncertainty in adoption rates, sensitivity analysis was done with low, moderate and high ceiling rates of adoption. The other variables for the simulation were kept at the base level as in Table 4.1.The results of the sensitivity analysis are presented in Table 4.5.

Table 4.5. Simulation results of aggregate economic benefits under different ceiling adoption rates of Bt eggplant

Maximum Adoption Rate	India	Bangladesh	Philippines
	NPV in US $		
25%	326,535,269	29,328,354	22,571,079
Baseline (35%)	410,744,687	36,883,219	28,379,353
45%	462,509,123	41,543,118	31,970,832
60%	768,682,033	69,047,161	53,128,717

The results indicate that at a low ceiling level of adoption (25%), the potential economic benefits would be about US $ 326 million to India, US $ 29 million to Bangladesh, and US $ 22 million to the Philippines, respectively. If the Bt technology is highly successful and widely adopted by the farmers, then at a 60% ceiling rate of adoption, the potential benefits would be US$ 768 million to India, US $ 69 million to Bangladesh, and US $ 53 million to the Philippines, respectively. The results show that even with a low adoption rate of Bt eggplant in these countries, the potential benefits from this technology are still high and justify the investments made for the development and diffusion of Bt technology in these countries. The baseline simulation assumed a linear annual adoption rate of 5% (*proportional increase per year in the area planted to Bt eggplant*), a sensitivity analysis with slower annual rate of adoption (2%-4%) and a low ceiling rate of adoption of 25% was done. The results of the sensitivity analysis are presented in Table 4.6.

Table 4.6. Simulation results of aggregate economic benefits under different linear annual rates of adoption of Bt eggplant

Linear annual rate of adoption	India	Bangladesh	Philippines
		NPV in US$	
2%	150,820,190	15,726,696	12,097,018
3%	198,463,954	20,698,580	15,923,745
4%	232,056,024	24,131,624	18,565,856

The results show that with a slow annual adoption rate of 2%, the potential economic benefits would be low and India would gain about US $ 151 million, while the gains to Bangladesh would be around US $ 16 million and the Philippines will gain around US $ 12 million. Thus, a slower rate of adoption will adversely affect the size of the welfare benefits. It is likely that the adoption rate of Bt eggplant may be faster in some regions but very slow at the national level as there are a large number of varieties of eggplant being grown in these countries. To develop Bt eggplant varieties, which are suitable for all agro-ecological conditions of a country and which are acceptable to consumers and farmers across the country will take longer than the research lag specified in the current model (4-6 years). Sensitivity analysis was also done to estimate the economic benefits using the low end assumptions where the expected increase in yield was kept at 15%, expected decrease in input cost at 15%, ceiling adoption rate of 20% and the linear annual adoption rate of 2%. Thus, all the parameters were kept at their minimum level to estimate the minimum level of potential benefits from adoption of Bt eggplant for these countries. The potential benefits for the low-end assumptions were around US$ 137 million for India, US$ 10 million for Bangladesh, and US $ 7 million for the Philippines..

4.1.2. Supply Elasticity:

Since own price elasticities of supply for eggplant in India, the Philippines and Bangladesh were derived from previous studies, simulations were done with different range of supply elasticities to estimate its effect on the total economic benefits. The results of the simulation are presented in Table 4.7.

Table 4.7. Simulation results of aggregate economic benefits from Bt eggplant adoption under different levels of price elasticity of supply

Supply Elasticity	India	Bangladesh	Philippines
	NPV in US $		
0.35	688,327,867	61,828,807	47,592,067
0.5	560,211,917	50,319,929	38,730,816
0.75	460,579,688	41,369,794	31,839,501
1.0	410,744,687	36,883,219	28,379,353

The results indicate that a relatively inelastic price elasticity of supply (0.35) provides more economic benefits than a unitary elastic price elasticity of supply (1.0). The consumer's share of total surplus decreases with a relatively inelastic supply of price and the producer's share of the total surplus increases. Similarly, when the price elasticity of supply is increased from a relatively inelastic level (0.35) to unitary elastic (1.0), the share of producer surplus to total surplus decreases, while the consumer's share of total surplus increases. A 1 percent change (increase) in price elasticity of supply results in about 0.37 percent change (decrease) in total economic benefits to India, Bangladesh and the Philippines. Thus, changes in price elasticity of supply affect both the size and the distribution of benefits between the producers and the consumers.

4.1.3. Demand elasticity:

Simulations for the baseline adoption scenario were done using price elasticity of demand data derived from previous studies conducted in this region, as the actual own price elasticities of demand for eggplant were not available for India, Bangladesh, and the Philippines. Since, the estimates used in the previous studies considered vegetables as a single group, it was assumed for the purpose of this study that demand for eggplant would follow the demand trend for vegetables in the country, without any difference in tastes and preference within the country. Therefore, sensitivity analysis was done with different ranges of own price elasticity of demand for eggplant to estimate its effect on the size and distribution of economic benefits in India, Bangladesh and the Philippines. The simulation results are presented in Table 4.8.

Table 4.8. Simulation results of aggregate economic benefits from Bt eggplant adoption under different levels of price elasticity of demand

Demand Elasticity	India	Bangladesh	Philippines	Ratio of consumer surplus to total surplus (%)	Ratio of producer surplus to total surplus (%)
	NPV in US $				
-0.35	407,509,406	36,602,399	28,176,962	74	26
-0.5	408,884,183	36,725,897	28,272,046	67	33
-0.75	410,651,752	36,884,681	28,394,296	57	43
-1.0	411,977,429	37,003,769	28,485,984	50	50

The simulation results from the sensitivity analysis (Table 4.7) show that changes in the own price elasticity of demand of eggplant have an insignificant (negligible) effect on the size of the total economic benefits from adoption of Bt eggplant. However, the distribution of the economic benefits changes significantly with the changes in demand elasticity. When the elasticity of demand for eggplant is unitary elastic (-1.0), total economic benefits are shared equally by the consumers and the producers. With a relatively inelastic elasticity of demand (-0.35), consumers capture about 75 percent of the total welfare benefits and the producers gain only 25 percent of the total welfare benefits.

4.1.4. Research Costs:

The baseline adoption scenario assumed the total research costs to be equal to the budgeted costs of the IPM-CRSP project for Bt eggplant in India, Bangladesh, and the Philippines. Since the actual investment for the development and diffusion of the technology is likely to be higher than the budgeted costs for the project, simulations were done with higher levels of research costs to estimate its effect on the size of the welfare benefits. The research lag period was assumed to be 4 years for India, and 5 years for Bangladesh and the Philippines. Research costs were assumed to be constant through the development stage of the project. Results of the simulations are presented in Table 4.9.

Table 4.9. **Simulation results of aggregate economic benefits from Bt eggplant adoption under different budgets of annual research cost**

Annual Research Cost US $	India	Bangladesh	Philippines
	NPV in million US $		
100,000	410 *(271 %)*	36 *(119%)*	28 *(108%)*
500,000	409 *(160%)*	35 *(61%)*	26 *(54%)*
750,000	408 *(139%)*	34 *(50%)*	25 *(44%)*
1 million	407 *(125%)*	33 *(43%)*	24 *(37%)*
2 million	403 *(96%)*	20 *(23%)*	28 *(28%)*
5 million	393 *(66%)*	15 *(13%)*	7 *(9%)*
Note: Figures in parentheses indicate the internal rate of return (IRR)			

The simulation results indicate that even with an annual research budget of US $ 5 million in each country, the total welfare benefits for India would be US $ 393 million with an IRR of 66%, while Bangladesh would gain US $ 15 million with an IRR of 13% and the Philippines would gain only US $ 7 million with an IRR of only 9%. When the annual research budget is set at a more realistic level of US $ 500,000, the welfare benefits to India are US $ 409 million with an IRR of 160%, while the returns in Bangladesh are US $ 35 million with an IRR of 61%, and welfare benefits in the Philippines are US $ 26 million with an IRR of 54%. The simulations show that India is in a position to make higher investments for the development and diffusion of the Bt eggplant as the size of its potential benefits is very high, while smaller countries like the Philippines and Bangladesh have a lower bound on their annual research costs (less than US $ 5 million).

India is taking the lead in the development of Bt eggplant and its investments are well justified by the high rate of return. The technology would then be transferred to Bangladesh and the Philippines, which is likely to help in keeping their research costs at a lower level. Limitations on infrastructure and resources make it difficult for Bangladesh and the Philippines to make large investments in the development of the Bt eggplant in their country. Thus, these countries would gain by the transfer of technology from India, which would then be used for the development of Bt eggplant using indigenous varieties suitable for local conditions in their country.

4.1.5. Success rate of project:

This study assumed a success rate of 100% for the research project for the development of Bt eggplant. There are various steps involved in the development and release of any new variety of crop especially genetically modified crop. Before the variety can be released commercially it has to undergo various safety tests as prescribed by the Bio-safety committee in the respective countries. The bureaucratic procedures involved in the research and transfer of genetically modified crops are quite complex and can delay its commercial release (*if successful*). To account for these uncertainties about the possible success rate of the technology, a sensitivity analysis was completed with different scenarios of the success of the project to estimate its effect on the size of the welfare benefits. The results of the simulations are presented in Table 4.10.

Table 4.10.Simulation results of aggregate economic benefits from Bt eggplant adoption under different scenarios of success

Success Rate	India	Bangladesh	Philippines
	NPV in US $		
0.35	141,909,509	12,743,100	9,806,218
0.5	203,349,062	18,262,321	14,054,515
0.75	306,55,706	27,533,553	21,190,023
1.0	410,744,687	36,883,219	28,379,353

The simulations indicate that the size of the welfare benefits are directly affected by the probabilities of success of the research project and in the same proportion. A probability of success of 50 % yields only 50 % of the total benefits generated by a 100 % success rate of the project. With a low success rate of 35%, the total welfare benefits would be US $ 142 million to India, US$ 13 million to Bangladesh, and US$ 10 million to the Philippines.

4.1.6. Summary of sensitivity results:

The sensitivity analysis shows that the size and distribution of welfare benefits is considerably affected by changes in the ceiling adoption rate and supply elasticity, while changes in the demand elasticity do not affect the size of the benefits, but affect the distribution of benefits between producers and consumers. The minimum welfare benefits from adoption of Bt eggplant with low end assumptions of a 15% increase in expected yield with a 15% decrease in input costs (*with a slow adoption and ceiling rate*) were estimated to be around US $137 million for India, US$ 10 million for Bangladesh, and US $ 7 million for the Philippines. The maximum benefits with a 45% increase in expected yield and a 45% decrease in input costs were estimated to be around US $ 773 million for India, US $ 69 million for Bangladesh, and US $ 53 million for the Philippines. Changes in the research costs and the success rate of the project have a significant effect on the size of the welfare benefits. Even with a high research budget for development and diffusion of the Bt technology, there are significant gains for all three countries, with the maximum benefits for India. Thus, India is in a position to make large investments for the development of this technology and help in transferring this technology to the Philippines and Bangladesh.

CHAPTER 5. SUMMARY AND CONCLUSION

The potential economic benefits from adoption of Bt eggplant in India, Bangladesh and the Philippines were estimated using an ex-ante partial equilibrium economic surplus model. The welfare benefits from the adoption of Bt eggplant were projected over the period 2003-2020. Since no baseline survey was conducted in these countries to estimate the likely response of farmers towards the new Bt technology, a baseline adoption scenario was first developed for the Bt eggplant using the adoption profile of other high yielding crops and Bt cotton, which has recently been released in India and China.

It was assumed that the farmers and consumers in these countries had few negative perceptions towards genetically modified food and Bt technology. It must be mentioned that with the exception of the Philippines, where genetically modified maize has just been released for commercialization, none of the countries have any genetically modified food crop yet available. Public response in these countries when genetically modified food crops are released for commercialization is uncertain.

In India, the response of farmers towards Bt cotton has been relatively enthusiastic despite some initial problems during its release and commercialization. Considering all the factors, the ceiling rate for adoption of Bt eggplant was kept low (35%) for the purposes of this study. It was also assumed that the response of farmers and consumers towards Bt eggplant would be same in all the three countries, which may not happen. Under the baseline adoption scenario (described in Table 4.1), the welfare benefits from the adoption of Bt eggplant are estimated at US$ 29 million in the Philippines, US $ 38 million in Bangladesh, and US $ 422 million in India. The simulation results indicate that consumers in all three countries would gain about 57 percent of the total welfare benefits, while the producers would gain only 43 percent. Welfare benefits were also estimated under alternative adoption scenarios with different levels of yield and input cost changes.

The minimum level of potential welfare benefits were estimated at US $ 19 million in the Philippines, US $ 26 million in Bangladesh, and US $ 286 million in India. The maximum level of potential welfare benefits were estimated at US$ 55 million in the Philippines, US $ 71 million in Bangladesh and US $ 794 million in India. Sensitivity analysis of the simulation results was completed on the effects of the price elasticity of supply, price elasticity of demand, and different ceiling adoption rates on the size and distribution of total welfare benefits. A low ceiling adoption rate of 25 percent would provide only US $ 22 million to the Philippines, US $ 29 million to Bangladesh and US $ 326 million to India in total welfare benefits, while a high ceiling adoption rate of 60 percent would generate about US $ 53 million for the Philippines, US $ 69 million for Bangladesh, and US $ 769 million for India.

Changes in the price elasticity of supply of eggplant affected both the size and the distribution of the welfare benefits, while changes in the own price elasticity of demand of eggplant affected only the distribution of the welfare benefits, with a small effect on total welfare benefits. Results of the simulation indicate that the potential benefits from adopting Bt eggplant in India, Bangladesh, and Philippines are very high in comparison to the investments made for the development and diffusion of the technology. India stands to gain the most from the adoption of Bt eggplant as it has a very large area under cultivation and it also has higher yield than Philippines and Bangladesh.

The adoption of Bt eggplant should result in about a 30 percent decrease in input costs to the farmers by the decrease in the usage of chemical pesticides in these countries. The farmers are likely to need at most 2-3 sprays for other insect pests, that are not targeted by the Bt toxin, compared to the current practice of spraying about 17-18 times. The environmental benefits from this reduction in the chemical pesticides usage are potentially enormous. The use of Bt eggplant will help in increasing the population of the natural enemies of the fruit and shoot borer, which are also affected by the use of pesticides. The Bt eggplant can be used in combination with other IPM techniques, which are environment friendly such as, using bio-control agents (*parasitoids*), botanical pesticides (*Azadirachtin*), insect attractants and traps etc.

Farmers will have less exposure to toxic chemicals that can have an adverse effect on their health, especially in developing countries, where precautions are not necessarily taken in handling and using pesticides. Consumers will also benefit from the reduction in usage of pesticides as there will be less exposure to the harmful residue on the eggplants, since some farmers do not follow the waiting period requirement after spraying and immediately harvest the crop and market it. Some of the toxic pesticides used in spraying eggplants are known to be carcinogenic to human beings if exposed over a long period of time.

It is difficult to directly place an economic value on these health benefits without extensive study, although the economic value of these health benefits may be high as the costs of medical treatment would be reduced and the economic efficiency of the farmers and the consumers increased. The reduction in pesticide usage might also help improve the quality of the environment by improving water quality, both underground and lakes and rivers, thus affecting the fish population in the river. High toxicity of river water is a major concern in some developing countries including India. Since rivers are the major source of water supply to the cities, it becomes important to take all measures necessary to reduce the level of pollution by cutting down the usage of chemical pesticides. There would also be indirect economic benefits from the adoption of Bt eggplant as the farmers would be able to invest the money saved on chemical pesticides on buying farm equipment or other economically productive activities to boost their income. However, there some major limitations of transgenic plants as stated below (Sharma et. al, 2000):

- transgenic plants are not able to provide protection against the secondary pests so some chemical sprays are required,
- cost of development and commercialization of transgenic crops is very high,
- insect migration can reduce the effectiveness of transgenic plants,

- effectiveness of transgenic plants is reduced by the development of insect resistance
- cross-contamination of other crops by pollen drift is a problem, especially on small farms in Asia,

There is concern among the farmers that a few large multinational corporations may dominate the seed market with transgenic crops and raise the seed prices limiting the options available to farmers. There is also concern among some consumers as to the effect of eating genetically modified (GM) food. There has been no evidence of adverse effects of eating GM foods except for some problems over Starlink corn in the U.S., which was suspected of causing allergy reactions in some cases. However, there has not been enough research on the effects of consuming GM foods to humans so extensive studies in this area may be required to gain consumer confidence towards GM food. These social concerns will also affect the regulatory mechanism for GM crops including Bt eggplant in India, Bangladesh, and the Philippines. It is possible that the commercialization of Bt eggplant might get delayed (*if it meets the existing biosafety protocols*) because of extensive testing and research required for this purpose to avoid any unexpected environmental problems.

5.1 Policy implications for technology transfer:

India has a strong infrastructure in place for agricultural research and the investment in agricultural research by private sector is highest in India in Asia (Pray & Fuglie, 2001). In small countries like Bangladesh and the Philippines the investment by private sector in agricultural research and development in much smaller as the returns from the investment are much lower because of limited size of the market. Strong Intellectual Property Rights (IPR) with a mechanism for enforcement help in providing stimulus to private research as the firms are able to capture the benefits of their research.

However investment by public sector is required for research focusing on providing environmental benefits and health benefits. India has a comparative advantage over the Philippines and Bangladesh in agricultural biotechnology research so the costs of development of Bt eggplant in India are lower. India already has a head start in Bt technology as the Bt eggplant has reached the field-testing stage so India is in a position to transfer its technology to Bangladesh and the Philippines. It is also easier to transfer the technological skills to develop the Bt eggplant then to physically export Bt eggplant from India because of quarantine and IPR restrictions in each country. If there are consistent protocols for field testing and commercialization of genetically modified plants in each country then it would help in better exchange of technology and enforcement and regulation of IPR. India can also transfer its technology on a fee basis to recover part of its investment, though it is too early to comment on that. USAID can play the role of facilitator in the transfer of technology from India to Bangladesh and Philippines. India also has monetary incentives in transferring the technology if part of the research cost is funded by the USAID. The transfer of technology will also help in building the regional cooperation between the countries and generating goodwill for India.

5.2. Limitations of the study and directions for further research:

This study provided estimates of the potential economic benefits from the adoption of Bt eggplant in India, Bangladesh and the Philippines, but there were several limitations of the analysis. The research cost used for the analysis was obtained from the IPM-CRSP project funded by the USAID for these countries. The research budget was available for only two years, i.e., 2002-2003. The development of Bt eggplant and its commercialization will take at least 4 years in India and 6 years in Bangladesh and the Philippines, so further investment would be required in the project for the commercialization of the technology. The research cost used for the analysis did not include the salary of the scientists involved and some other expenses, as they were covered by the respective organizations involved in the project. However, the potential benefits from the adoption are much higher and would not be affected considerably when all the costs are included.

As this study had an ex-ante analytical framework, there were no reliable estimates on the adoption. Assumptions were made about the possible adoption path of the Bt eggplant in India, Bangladesh and the Philippines from other studies and from other crops released in these countries. Changes in the adoption path can have a major effect on the size and the distribution of welfare benefits. Since there have been some instances of protest against genetically modified crops in the Philippines and India, the ceiling adoption rate was kept low, which could also be affected by the social perceptions against Bt technology when it is released. It was assumed that tastes and preferences for the eggplant are uniform in all three countries. The Bt eggplant would be developed by transferring the Bt genes to the popular local varieties in the given countries. The popularity of a variety varies considerably within a country, especially in one the size of India. It would take some time before Bt eggplant varieties acceptable and suitable for all regions are developed, which would affect the rate of adoption.

Data regarding the price elasticity of supply and demand for eggplant, were not available for the given countries, so elasticity estimates from previous studies were used, which were somewhat outdated. However, sensitivity analysis showed that the size of the benefits would not be affected by the changes in the demand elasticity. Since the Bt eggplant is still in the development stage and has not been field-tested, assumptions regarding yield and input cost changes from its adoption were made. Scientists involved in the development of Bt eggplant were interviewed to get possible estimates regarding these parameters. The size and distribution of the welfare benefits would be affected considerably with changes in these parameters.

The price data used for the analysis were the average wholesale prices for the country, but there were large variations in prices within the countries and from one season to another. The distribution of benefits within the country would vary considerably and some regions would gain more than the others depending on the demand and supply of eggplants. The study assumed that the Bt eggplant is being developed by the public sector, but there are some private companies involved in the development of Bt crops including Bt eggplant as well, which might affect the adoption path used in the analysis if they are able to commercialize it first.

The economic value of the environmental benefits from the adoption of the Bt eggplant could not be precisely estimated and could be an area of further research. Further study in this area should involve a survey of farmers to study their perceptions towards genetically modified crops and Bt technology in particular. The study assumed a closed economy model for the analysis with no international trade in eggplants, although the small amount of eggplants exported to the UK from Bangladesh might be affected once Bt eggplant is released in Bangladesh.

Further studies should also focus on the integration of Bt eggplant with other IPM practices to develop an IPM package for the farmers that may be diffused by extension agents and NGO's. Farmers may need to be made aware of the benefits of the Bt technology by education, field tours and other social awareness measures to counteract the negative publicity against genetically modified crops in some regions of these countries.

REFERENCES:

Aerni, P., Anwander Phan-huy, S. and Rieder, P, 1999. "An Indication of Public Acceptance of Transgenic Rice in the Philippines." *Biotechnology and Development Monitor*, No. 38: 18-21.

Aerni, P, 2001. "Assessing Stakeholder Attitudes to Agricultural Biotechnology in Developing Countries." *Biotechnology and Development Monitor,* No. 47: 2-7.

Aganon, T.M., Patricio, M.G., Calderon, J.J., Soriano, J.S., and Sison, M.L.J, 1997. "Development of a Vegetable IPM Program in a Rice-Based Cropping System." *Kasetsart Journal Natural Science,* 32: 32-36.

Ahmed, A.U., and Yawar Shams, 1994. "Demand Elasticities in Rural Bangladesh: An Application of the AIDS Model." *The Bangladesh Development Studies* Vol. XXII, No. 1: 1-23.

Ahmed, R, 1981. "Agricultural Price Policy under Complex Socio-economic and Natural Constraints: The Case of Bangladesh". Rep. 27, International Food Policy Research Institute, Washington, DC, 78pp.

Alam, S., Karim, A.N.M. and Nurullah, C.M., 1981. "Insecticide use on rice in Bangladesh". *Bangladesh Journal of Agricultural Research*, 6:37-50.

Ali, Mubarak, and Hau, Vu Thi Bich, 2001. "Vegetables in Bangladesh: Economic and Nutritional Impact of New Varieties and Technologies". Asian Vegetable Research and Development Center, Technical Bulletin No. 25, 55p.

Alston, J.M., Norton, G.W., and Pardey, P.G., 1995. *Science Under Scarcity: Principles and Practices for Agricultural Research Evaluation and Priority Setting*. Ithaca, NY: Cornell University Press.

Askari, H., and Cummins, J., 1976 *Agricultural Supply Response: A Survey of Econometric Evidence*. Praeger, New York, 443p.

Bajet, C.M., Peralta, G.A., Bato S., Bariuan, F.V., 2001. "Pesticide Management of Major Pests & Diseases of Eggplant." Online text accessed from http://www.bar.gov.ph/cmb%20pestimng%20progressreport.htm

Bangladesh Bureau of Statistics (BBS), 1999. *Yearbook of Agricultural Statistics of Bangladesh.* Dhaka, Bangladesh.

Bangladesh Bureau of Statistics (BBS), 2000. *Statistical Yearbook of Bangladesh*. Dhaka, Bangladesh.

Binswanger, Hans, Yang, M.C., Bowers, Alan and Mundlak, Yair, 1987. "On the Determinants of Cross-Country Aggregate Agricultural Supply". *Journal of Econometrics,* 36: 111-131.

Botrell, D.R., 1979. *Integrated Pest Management*. Council on Environmental Quality. Washington D.C.: U.S. Govt. Printing Office.

Carpenter, J.E., Sankula, S., Silvers, C.S., Gianessi, L.P, 2002. "Plant Biotechnlogy: Current and Potential Impact for Improving Pest Management in U.S. Agriculture: An Analysis of 40 Case Studies". June 2002, National Center for Food and Agricultural Policy, Washington, DC.

Chibber,A. (1982). *Dynamics of Price and Non Price Response of Supply in Agriculture.* Stanford University, Stanford. CA.

Cuyno, L.C.M., Norton, G.W., Rola, A., 2001. "Economic Analysis of Environmental Benefits of Integrated Pest Management: A Philippine Case Study". *Agricultural Economics*, 25:227-233.

Davis, J.S., P. Oram and J.G. Ryan. *Assessment of Agricultural Research Priorities: Ann International Perspective.* Canberra and Washington, D.C: Australian Centre for International Agricultural Research and International Food Policy Research Institute, 1987.

Daku, Lefter. S., 2002. "Assessing Farm-Level and Aggregate Economic Impacts of Olive Integrated Pest Management Programs in Albania: An Ex-Ante Analysis". PhD Dissertation, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University.

Department of Agriculture- Agribusiness and Marketing Assistance Service (DA-AMAS), 2001. *Commodity Factsheet, 2001, Eggplant*. Bureau of Agricultural Statistics, Government of Philippines.

Dhaliwal, G.S., and Arora, R., 2001. *Integrated Pest Management- Concepts and Approaches.* Kalyani Publishers, New Delhi, pp: 86-87.

Estruch, J.J., Carozzi, N.B., Desai, N., Duck, N.B., Warren, G.W. and Koziel, M.G., 1997. "Transgenic Plants: An Emerging Approach to Pest Control." *Nature Biotechnology,* 15: 137- 141.

Fan, Shenggen., Gail Cramer, Eric Wailes.,1991. "Food Demand in Rural China: Evidence from Rural Household Survey." *Agricultural Economics*, 11: 61-69.

Fernandez-Cornejo, J., 1994. "Nonradial Technical Efficiency and Chemical Input Use in Agriculture". *Agricultural and Resource Economics Review,* 23 (1): 11-21.

Fernandez-Cornejo, J. and W. Mc Bride., (2000). "Genetically Engineered Crops for Pest-Management in U.S. Agriculture". Economic Research Service, U.S. Department of Agriculture, Washington D.C.

Intergovernmental Forum on Chemical Safety (IFCS), 1996. "Philippine Case Study: A Developing Country's Perspective on POPs." Paper presented at the IFCS meeting on POPs, 17-19, June, 1996- Manila, Philippines. Online text accessed from *http:// www.chem.unep.ch/pops/indxhtms/manexp7.html*

Goldman, H.W., and Ranade C.G., 1976. "Food Consumption Behaviour by Income Class in Rural and Urban Philippines." Occasional Paper, No. 90. Department of Agricultural Economics, Cornell University, Ithaca, N.Y.

Guldager, K.Ferrer, 1977. "The Demand for Selected Agricultural Products for Household Consumption 1970-1980." Unpublished MSc thesis, Asian Social Institute, Manila.

Hareau, Guy G, 2001. "The Adoption of Genetically Modified Organisms in Uruguay's Agriculture: An Ex-Ante Assessment of Potential Benefits". Masters Thesis, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University.

Higley, L.G., Wintersteen, W.K., 1992. "A Novel Approach to Environmental Risk Assessment of Pesticides as a Basis for Incorporating Environmental Costs into Economic Injury Level". *American Entomologist,* 38:34-39.

Huang, K.S. and B.H. Lin, 2000. *Estimation of Food Demand and Nutrient Elasticities from Household Survey Data.* Washington DC: U.S. Department of Agriculture, Food and Rural Economics Division, Economic Research Service. Technical Bulletin No. 1887, August 2000.

Islam, S., 2002. "Integrated Pest Management (IPM) and Green Farming in Rural Poverty Alleviation in Bangladesh". Department of Agricultural Extension, Bangladesh. Online copy of text accessed from http://www.unescap.org/rural/doc/ipm2002/ch01.pdf

Jaffe, Steven, 1991. "Marketing African Horticultural Exports: A Transaction Cost Perspective." Paper presented at the Workshop on Globalization of the Fresh Fruit and Vegetables System, University of California, Santa Cruz, Dec 6-9.

Kogan, M., 1998. "Integrated Pest Management: Historical Perspectives and Contemporary Developments". *American Review of Entomology,* 43: 243-270.

Kunkel, D.E., Alix J.C., and Orogo V, 1978. "Estimates of Demand Elasticities for Selected Agricultural Products in Major Philippine Areas: Manila, Urban and Rural Areas, 1976-1980." *Journal of Agricultural Economics and Development,* 8: 97-121.

Mamaril, C.B., 2002. "Transgenic Pest Resistant Rice: An Ex-Ante Economic Evaluation of an Adoption Impact Pathway in the Philippines and Vietnam for Bt Rice." Masters thesis, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University.

Mangahas, M.,Recto, A. and Ruttan V, 1966. " Price and Market Relationships for Rice and Corn in the Philippines". *Journal of Farm Economics,* 48: 685-703.

Marshall, A, 1890. *Principles of Economics*. Macmillan, London.

Masud, S.M., Lacewell, R.D., Taylor, C.R., Benedict, J.H., and Lippke, L.A., 1981. "Economic Impact of Integrated Pest Management Strategies for Cotton Production in the Coastal Bend Region of Texas". *Southern Journal of Agricultural Economics*, Vol. 13 (2): 47-52.

Mills, Bradford, 1998. "Ex-Ante Research Evaluation of and Regional Trade Flows". *Journal of Agricultural Economics*, 49 (3): 391-406

Mishan, E.J., 1981. *Introduction to Normative Economics*. NewYork: Oxford University Press.

Mullen, J.D., Norton, G.W., Reaves, D.W., 1997. "Economic Analysis of Environmental Benefits of Integrated Pest Management". *Journal of Agricultural and Applied Economics*, 29 (2): 243-253.

National Horticulture Board (NHB), 2002. *Horticultural Statistics at a Glance*. Ministry of Agriculture, Government of India.

Norton, G.W., and J. Mullen. "Economic Evaluation of Integrated Pest Management Programs: A Literature Review." Report 448–120, Blacksburg, Virginia Cooperative Extension, March 1994.

Norton, G.W., Pardey, P.G., and Alston, J.M., 1992. "Economic Issues in Agricultural Research Priority Setting". *American Journal of Agricultural Economics,* 74: 1089-1094.

Norton, G.W., Ganoza, V.G., and Pomareda, C., 1987. "Potential Benefits of Agricultural Research and Extension in Peru". *American Journal of Agricultural Economic,* 69: 247-257.

Peterson, W., 1979. "International Farm Prices and the Social Cost of Cheap Food Policies." *American Journal of Agricultural Economics,* 59: 12-21.

Pilcher, C.D., Rice, M.E., Higgins, R.A., Steffey, K.L., Hellmich, R.L., Witkowski, John, Calvin, Dennis, Ostlie, K.R., and Michael Gray., 2002. "Biotechnology and the European Corn-Borer: Measuring Historical Farmer Perceptions and Adoption of Transgenic Bt Corn as a Pest Management Strategy." *Journal of Economic Entomology*, Vol.95 (5): 878-892.

Pimental, D., H. Acquay, M. Biltonen, P. Rice, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Horowitz, and M. D'Amore., 1992. "Environmental and Economic Costs of Pesticide Use." *BioScience*, Volume 42 (10): 750-760.

Pingali, P.L., and Roger, P.A., 1995. *Impact of Pesticides on Farmer Health and The Rice Environment.* Kluwer Academic Publishers, Norwell, MA.

Pray, C.E., and Fuglie, K.O. "Private Investment in Agricultural Research & International Technology Transfer in Asia." Washington DC: U.S. Department of Agriculture, Economic Research Service, Agricultural Economics Report No. 805, November, 2001.

Qaim, Matim, Zilberman, David., 2003. "Yield effects of Genetically Modified Organisms in Developing Countries." *Science*, Volume 299 (5608): 900-902.

Rajotte, E.G., Kramer, R.A.,Norton, G.W., Greene, C.R., and McPherson, R.M., 1985. "An Economic Analysis of Soybean Integrated Pest Management". *American Journal of Agricultural Economics,* Vol. 67 (3): 567-572.

Rao, J. Mohan., 1989. "Agricultural Supply Response: A Survey". *Agricultural Economics,* 3:1-22.

Rashid, M.A. et al., 2001. "Varietal Screening of Eggplant for Resistance to Bacterial Wilt, Fruit and Shoot Borer. Leafhopper and Root-knot Nematode, and of Tomato for Resistance to Bacterial Wilt, Virus Disease and Root Knot Nematode". Integrated Pest Management Collaborative Research Support Program.Eighth Annual Report, Office of International Research and Development, Virginia Tech.

Rubatzky, V.E., and Yamguchi, M., 1997. *World Vegetables- Principals, Production and Nutritive Values*, 2nd edition Westport CT: Chapman & Hall Publishing, Inc pp.843.

Sharma, H.C., Sharma, K.K., Seetharama, N., Oritz, R., 2000. " Prospects of Using Transgenic Resistance to Insects in Crop Improvement." *Electronic Journal of Biotechnology*, Vol. 3 No.2: 76-96.

Yatopoulos, P. and Lau, L., 1974. "On Modelling the Agrarian Sector in Developing Countries: An Integrated Approach on Micro and Macroeconomics." *Journal of Developmental Economics,* 1: 105-127.

Zhao, Jianzhou., 1998. “The Resistance and Countermeasures of Cotton Bollworm to Bt Cotton.” *Agricultural Biotechnology Newsletter*, No.2:1-2. (internal publication)

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