Is it Feasible to Provide Genetically Modified Crops to Small Farmers on Preferential Terms? : An *Ex Ante* Analysis of Bt Eggplant in India

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Abstract

Is it feasible to provide genetically modified crops to small farmers on preferential terms? Who benefits from introducing technologies targeted at resource-poor farmers? Building on the literature on assessing the welfare benefits from introduction of technologies developed by suppliers of agricultural inputs (private sector), we conduct an *ex ante* analysis of the distribution of the benefits from introducing Bt eggplant in India. Using data from the contingent valuation survey, we also assess the economic viability of the public-private partnership involved in the development of Bt eggplant. Our study showed that consumers gain maximum of the total surplus generated (60%) due to the introduction of Bt hybrid technology while innovator's gain is about 7%. Even though the company has a wide range of prices to select from, marketing Bt hybrid seeds at an affordable price increases the total surplus generated without affecting company's share of rents significantly. Our data and analysis clearly show that many farmers growing traditional varieties (Open Pollinated Varieties (OPVs)) are willing to adopt Bt OPV provided their varietal preference criteria are met. Our study suggests that providing Bt OPV on preferential terms to resource-poor farmers would not be detrimental to the firm's interest. Even though, due to the low price of Bt OPV some of the farmers decided to adopt Bt hybrid might shift to Bt OPV, most of the hybrid growers would prefer Bt hybrid over Bt OPV. The size and distribution of benefits would change as more Bt eggplant varieties are made available, but results from our study provide an initial empirical estimate of potential benefits arising from the introduction of Bt eggplant in India.

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1:Introduction

Research and development in agricultural biotechnology mainly addresses the issue of declining/ plateauing agricultural productivity by introducing technologies aimed at providing resistance/tolerance to biotic and abiotic stresses such as pests, drought, and salinity. The year 2005, marks the tenth anniversary of the commercialization of genetically modified (GM) crops.

Global area of approved biotech crops in 2005 was 90 million hectares, spanning 21 countries. Remarkably, the global area under biotech crops increased more than fifty-fold in the first decade of commercialization (James 2005,). This unparalleled diffusion of the new agricultural technology raises questions such as what promoted this increase in research and development (R&D) of agbiotech, and what are the welfare effects of these innovations.

The publicly sponsored research institutions have and are actively involved in agricultural research; it is a fact that an increasing proportion of R&D in agriculture is performed by private firms that typically supply inputs to agriculture. These innovations produced by private firms are usually protected by intellectual property rights (IPRs) which confer monopoly rights to the innovator (Moschini et al. 1999,). The enforcement of IPRs for biological innovations spurred private investments in agriculture biotechnology. The available information on the relative sources being invested by various stakeholders in agricultural biotechnology research clearly shows that vast majority (about 65-80 %) of the research is carried out by private sector in developed countries and they focus on crops important for farmers in developed countries (FAO 2002,). In this context, institutional changes fostering increased collaboration and partnership between private and public sector R& D in agbiotech are crucial to address the issues faced by small and poor farmers in developing economies. In addition, it is equally important to assess the welfare effects and economic viability of such a public-private partnership.

The public-private partnership involved in the development of Bt eggplant in India is unique in the context of developing economies, where private sector develops Bt hybrid seeds and charge a premium for the Bt gene, while donating the technology royalty-free to the public sector for developing Bt OPVs (Open Pollinated varieties). In this paper, we conduct an *ex ante* analysis of the distribution of benefits from introducing Bt eggplant among different stakeholders, and also assess the economic viability of such a partnership in the Indian context.

2:Background on the Public-Private Partnership in R&D of Bt eggplant and its significance in India

Eggplant-*Solanum melongena* L. (known as *brinjal* locally), is an economically important vegetable crop in many countries of Asia and Africa. India is considered as one of the centers of origin of eggplant (Vavilov 1951,). In the past, farmers maintained and supplied seeds of eggplant which resulted in special type of varieties getting adapted in the region. Since late 1980s, there is an increasing number of F_1 hybrid varieties bred by private seed companies. Private sector contributes 64% of market share of vegetable hybrids while only 3% is from public sector.

The eggplant shoot and fruit borer (*Leucindoes orbonalis*) is the major insect pest of eggplant throughout Asia (Allam, Rao, and Rao 1982,). Larvae of ESFB bore into shoots during vegetative growth stage and later into flowers and fruits rendering fruit unfit for human consumption. Since the pest feeds on shoots and fruits, crop damage occur throughout the crop season starting from transplanting. Previous studies assessing the impact of ESFB damage reported yield loss up to 70% in Indian conditions (Dhandapani, Shelkar, and Murugan 2003, 330-339). Even though Integrated Pest Management (IPM) practices such as pheromone traps are available to control the pest, farmers choose chemical insecticides because they are readily available, highly advertised, and easy to apply (Cork et al. 2003, 1-13). Control by toxic insecticides applied frequently threatens the health of producers and consumers, pollutes environment, and raises prices. In addition, wide spread use of broad spectrum insecticides might kill beneficial insect population and result in resurgence of other pests like thrips and mites on eggplant fields.

The search for alternatives to heavy reliance on chemical pesticides for controlling the pest, led to the development of Bt eggplant (Genetically Modified) by a private company Mahyco (a Monsanto subsidiary) in India. GM eggplant contains a Bt gene obtained from the bacterium, *Bacillus thuringiensis*, which produces a protein toxic to ESFB. Even though public institutes such as Indian Agricultural Research institute (IARI) and Indian Institute of Horticulture Research (IIHR) also work on development of Bt eggplant quite independently, their R& D is at a less advanced stage compared to that of Mahyco, which developed Bt hybrid eggplant by inserting the Bt gene into its own hybrid varieties.[1]

Under the ABSP II (Agricultural Biotechnology Support Program) project funded by USAID (United States Agency for International Development), Mahyco donated the Bt gene to leading public institutes in India, such as Tamil Nadu Agricultural University, University of Agricultural Sciences- Dharwad, and Indian Institute of Vegetable Research. Mahyco also has collaborations with national institutes in Bangladesh and the Philippines. This public-private partnership is aimed to make pesticide-substituting Bt seeds available at affordable prices for resource-poor farmers in developing countries. The development of Bt OPV (by inserting Bt gene into most popular OPVs) is under progress in various public institutes. Bt OPVs are expected to be commercialized after 2-3 years of introduction of Bt hybrid eggplant in India.

Given that most of the Indian eggplant farmers grow OPV eggplant (adoption of hybrid eggplant is 30% in India-(Kataria 2005,), commercialization of Bt hybrid eggplant by a private company while donating the Bt technology to public sector for development of Bt OPVs is very unique in the context of developing economies where access to technology by poor farmers is a major issue. The key questions arising from this partnership are; what are the welfare effects of this public-private partnership? Will the private company be able to make profits once Bt OPV seeds are marketed at a cheaper price relative to Bt hybrid seeds? In other words, is it economically feasible for the private company to charge a very high premium for Bt hybrid seeds while donating the Bt technology to public institutes? Whether the preferential pricing (on cost basis and not on profit motive) of Bt OPV seeds by public institutes result in reduced demand for Bt hybrid seeds which could affect the economic viability of the public-private partnership? As it

[1] Monsanto sub-licensed its Bt gene to Mahyco, and Mahyco conducted further R&D for developing Bt eggplant.

is the first case of such a public-private partnership in India, it is important to see the effects of introduction of Bt OPV seeds on the market potential of Bt hybrid seeds. Combining data from the farm-level survey, field trials and other secondary sources, we tray to answer these questions in the Indian context.

According to our survey hybrid and OPV producers follow quite different production practices, where higher input hybrid production system has significantly higher yield than OPV production system. Further, Bt hybrid and Bt OPV seeds of eggplant are expected to be commercialized with some time gap. Hence, the welfare effects of introduction of Bt eggplant are evaluated separately for these two technologies after accounting for the investment sources for respective R&D.

3:Methods

3:1 Conceptual framework for the welfare analysis

In the past, most of the innovations were developed by the public sector and were introduced into perfectly competitive agricultural markets. Under such conditions total welfare changes due to the introduction of new technology can be measured as the changes in consumer and producer surplus using the methods summarized in (Alston, Norton, and Pardey 1995, 585). Technological changes due to research in agriculture increases the yield or reduces the cost of production once the new technology is adopted. If the technology is yield increasing and the demand is downward sloping, a shift in the supply curve due to the increased production results in lowering the prices in the commodity market. Alternatively, a cost reducing technological change allows the producer to sell the same quantity at a lower price than before. In both the cases, a new equilibrium is formed due to a shift in the supply curve, and the new equilibrium is achieved at a lower price and higher quantity. As a consequence of the new equilibrium, changes occur in the consumer and producer surplus. This change due to a shift in the original supply curve S is shown graphically in Figure (1). The total surplus change is given by area A_1B_1BA, which is the sum of the change in producer surplus (area $P_1B_1A_1$-area PBA), and the change in consumer surplus (area PBB_1P_1).

Figure 1 here

Even though public institutions have been and are actively involved in the agricultural research, recent developments in agricultural biotechnology especially in the case of GM crops clearly show that most of R&D in agricultural biotechnology is performed by private firms. The innovations developed by private sector are usually protected by IPRs, which provide incentives for the innovators to invest more in R&D. It is also a fact that the agents endowed with IPRs for the innovations would exploit them to maximize their profits.[2] Hence for innovations protected by IPR, the competitive pricing conditions underlying the conventional approach illustrated in (Alston, Norton, and Pardey 1995, 585) (Figure 1), can not be used to evaluate the welfare benefits from the adoption of new technology.

Since Bt hybrid eggplant is developed by Mahyco and the innovation is assumed to be drastic (the innovating firm is unconstrained in charging a premium), we follow the (Moschini and Lapan 1997, 1229-1242)framework to analyze the distribution of benefits among different economic agents from adopting Bt hybrid technology. Moschini and Lapan modeled a case in which IPR protection imparts temporary monopoly power on the introduction of an innovation in the input market. The reasoning was based on the fact that IPR confer limited monopoly power to the company (innovator). According to the model, the new technology was embedded in seeds (agricultural input), where innovator could charge a price higher than the marginal cost of producing the innovation. Authors argued that under such situations, the monopoly profits generated in the input market need to be accounted for while evaluating the welfare changes after an agricultural innovation is adopted.

[2] In the case of Bt cotton in India, the private company(ies) are charging on average, four times the price of conventional cotton hybrid seeds, even after sublicensing the Bt technology to competitors in the market.

Since the conventional economic surplus approach is based on the commodity market, and the monopolist's profit is produced in the input market, the adjusted theoretical model of Moschini and Lapan proposes to evaluate the total welfare changes as the sum of the changes in the Mrashallian surplus on agricultural commodity market, and the monopoly profit in the input market. We extend this model to an *ex ante* analysis of the potential welfare benefits of Bt eggplant in India, where a public-private partnership is involved in the introduction of the technology. Because of the public good nature associated with Bt OPV eggplant (recognizing the no-profit motive of the public sector), the gross benefits from the introduction of Bt OPV eggplant can be evaluated using the conventional framework illustrated in Alston et al., 1995. Because of the limited monopoly power of the innovator (private company) of Bt hybrid technology, the conventional framework fails to capture the potential gross welfare benefits from the introduction of the technology. Hence, we follow the Moshini and Lapan framework in estimating the potential welfare benefits from the introduction of Bt hybrid technology, and the details are given below.

As Bt seeds could substitutes the conventional seeds and reduce the extent of pesticide use, following Moshini and Lapan framework, we assume that the new technology (Bt) substitutes the old one (conventional seeds), and both are related to each other by an augmentation factor α. This augmentation factor allows the comparison of new and old input use in terms of efficiency units. The relationship can be represented as

$$g(x_1, z) = f(\alpha x_1, z), \quad \text{and} \quad \alpha > 1 \qquad (1)$$

where, g() represents the new production technology as a function of the new input and a set of all other inputs, z. The old technology is represented by f (), and the amount of the new input is multiplied by the augmentation factor α, as it requires more efficiency units of x_1 to substitute the old input in f (). In efficiency units, the pre-innovation technology input quantity can be written as $x_0^{'} \equiv x_0$, and the post-innovation technology quantity is $x_1^{'} \equiv \alpha x_1$. Similarly, the input prices are represented as $w_0^{'} \equiv w_0$, and $w_1^{'} = (w_1 / \alpha)$. Let P, be the commodity price, then the indirect profit function in efficiency terms can be given as

$$\Pi(P, w', r) \equiv \max_{x',z} \{ p(f(x', z) - w^{'} x^{'} - rz \} \qquad (2)$$

Applying Hotellings Lemma to the indirect profit function gives the general expression for output supply y^*, and the input demand curve x^* as follows,

$$y^* = \Pi_p(p, w^{'}, r) \qquad (3)$$

$$x^* = -\Pi_{w^{'}}(p, w^{'}, r) \qquad (4)$$

where, the subscripts p, and w', refer to the partial derivatives, and r, is the price for other set of inputs. Farmers will adopt Bt technology if the value of cost reduction plus the increase in yield is greater than the price differential between Bt and non-Bt varieties.

It is reasonable to assume that both types of varieties (Bt and conventional seeds) are produced at constant marginal cost c, and that the prices of other inputs, (r), are exogenous to the eggplant sector. Then the profit of the innovator of Bt hybrid technology is given by

$$(w_1 - c)x_1 = (w_1^{'} - \frac{c}{\alpha})x_1^{'} \qquad (5)$$ in efficiency units.

Because of IPR protection, the firm is able to charge a monopolistic price w_1^m. Therefore the derived demand for Bt hybrid, and the monopoly price measured in efficiency units are

$$x(w') \equiv x(p(w^{'}, r), w^{'}, r) \qquad (6)$$

$$w_1^m \equiv \arg\max\{(w_1^{'} - \frac{c}{\alpha})x(w^{'})\} \qquad (7)$$

Since the two inter related factors that need to be considered in describing how the price for the new innovation is determined are a) the previously existing market structure and b) whether the innovation is drastic (leading to unconstrained monopoly price of the innovated input) or non-drastic (so that the monopolist's pricing decision is constrained by threat from competition) (Moschini and Lapan 1997, 1229-1242). In this study we assume that existing hybrid seed market is competitive,[3] and the innovator of Bt technology is unconstrained in pricing the new input $(w_1^m < c\alpha)$, where w_1^m is profit maximizing monopolist's price per efficiency units of the innovation, and c, the marginal cost of producing the input. In this case, the original market structure does not affect the price charged for the innovated input. However, there is an impact in the commodity market due to the decline in price (in efficiency units) of the input. Analytically, the decline in efficiency price of the input leads to higher output and lower price in the commodity market. However, the total welfare effects cannot be measured in the commodity market alone, because the change in monopoly rents accruing to the company are not represented in the commodity market.

Assuming that competition prevails in the current input market prior to the introduction of innovated input (Bt hybrid seeds), the welfare gain from a drastic innovation is given by

$$\Delta SW^{D,C} = \int_{w_1^{',m}}^{c} x(w^{'})dw^{'} + (w_1^{',m} - \frac{c}{\alpha})x_1^{',*} \qquad (8)$$

The first term on the right-hand side of the equation is equivalent to the change in total surplus measured in the output market, and the second term accounts for the monopolist's profit produced in the input market. Graphically, the total benefits given by equation (8) can be represented in the input market as shown in Figure (2). The demand for efficiency units of the improved input is expressed as the function of its price w. In figure 2, MR is the marginal revenue curve of the innovator (monopolist's), $w_1^{',m}$ and $\frac{c}{\alpha}$ are the price per efficiency unit of the new input and the marginal cost per efficiency unit respectively. The efficiency price of the old input is given by $W_0^{'}$, while $X_0^{'}$ and X_0^{c} are the effective demands for efficiency units of the old input under pre-existing monopoly and under perfect competition respectively, and $X_1^{'}$ is the demand in

[3] This assumption is reasonable in the Indian context, where large numbers of national and international seed companies are present in the vegetable seed market.

efficiency units of the new input. The sum of the areas 4, 5, 6, and 7 in figure 2 represents the change in Marshallian surplus and is equivalent to the change in economic surplus calculated in the output market under the conventional approach (as in the case of Bt OPV seeds). The monopolist's profit (innovator of Bt hybrid) is represented by the sum of areas marked as 8,9,10, 11, and 12 in figure 2.

Figure 2 here

3:2 Data collection

We conducted a farm-level survey for 2004-2005 cropping year in Maharashtra, India, during December 2004-February 2005. Our survey covered four major eggplant growing districts of the state: Jalgaon, Nagpur, Ahmad Nagar, and Nanded. We used the following sampling procedure to select the 290 households included in the survey: districts were chosen to represent the four major geographical zones (Marathwada, Vidarbha, Khandesh, and Western Maharashtra) of the state, and to collect information on different market segments of eggplant. The survey covered 20 *talukas* (a revenue division smaller than district) and 38 villages from the four selected districts, and these sampling sites were chosen because they were known to include farmers producing substantial amounts of eggplant. Farmers were selected randomly from the list of eggplant farmers or from the list of all farmers provided by the village administrative authorities. In addition, general information on the sample villages was collected from the village administrative authorities.

The questionnaire consisted of three parts. The first part included questions on general cropping pattern, years of growing eggplant, adoption details of hybrid seeds, and detailed cultivation practices for eggplant. Questions about farmers' knowledge of and perceptions towards Bt technology, their willingness to adopt Bt hybrid seeds, their preference towards Bt OPV seeds and questions exploring their Willingness To Pay (WTP) were included in the second part.[4] In the survey, farmers were informed about the potential benefits of Bt technology based on the information gathered from the scientists working in the field. The surveyed farmers were told that the Bt hybrids are expected to reduce insecticide use against ESFB by 70-75% and an yield increase of about 30% over conventional hybrids. All of the surveyed farmers cultivating hybrid eggplant purchased new seed packets each year as they were aware of the yield reduction associated with the F_2 generation seeds. In the case of Bt OPV, since the research was at an earlier stage during the survey, the same benefits as Bt hybrid were attributed to the technology while farmers were reminded that once purchased Bt OPV seeds, they could save and use the seeds from the previous crop. Income and demographic details were included in the last part of the questionnaire. According to the latest statistics available from Maharashtra State Seed Corporation, 60% of the total area under eggplant in the state is covered by hybrid eggplant.

3:3 Data from the Field Trials of Bt Eggplant

The first round of filed trials for Bt hybrid eggplant was conducted in 11 locations, covering seven states (Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Punjab, and Uttar Pradesh) in India, during 2004-2005. Five Mahyco hybrids- MHB-80 Bt, MHB-4 Bt, MHB-10 Bt, MHB-9 Bt, and MHB-99 Bt suitable for different agro-climatic conditions were evaluated in these trials. Field trials of three additional hybrids, MHB-11Bt, MHB-39 Bt, and MHB-112 Bt were conducted in six locations in the year 2005-2006. In each trial location, Bt hybrid was grown next to non-Bt counter parts, and other conventional checks (Popular OPV, Competitor's hybrid). Each trial location consisted of 20 plots with five replications of each of the four types (Bt hybrid, non-Bt counterpart, competitor's hybrid, and

[4] For the WTP question, the first bid offered was Rs 400/10 gm packet of hybrid brinjal, and if the response was no, a lower bid was offered .The lower bids offered were: Rs 350, Rs 300, Rs 250, Rs 200, and Rs 150. The bid ranges were chosen to cover what we perceived to be a likely range of retail prices, and WTP for Bt hybrid seeds. In addition, farmers were asked to state their preference towards Bt OPV, and their WTP for the technology (open ended). This approach was followed to correspond to the current market scenario of OPV seeds, where seeds are marketed at a cheaper price-Rs 16/50 gm packet

popular OPV). The net plot size was 16.2 m^2, thus the five replications resulted in an area of $81m^2$ for each type. The data from field trials were extrapolated on per acre basis for further analysis.

The trials were managed by the company entomologists and agronomists. Pesticide sprays on trial plots were done based on the Economic Threshold Level (ETL). Although, the limited number of field trials may not be sufficient for broad generalizations about the technology, they do indicate the economic potential of the technology. Since we have the detailed information on yields and pesticide applications from the first set of field trials (2004-2005), we report the summary of the field trial results in Tables 1 and 2.

Tables 1 and 2 to be included here

Based on the information available to us, the average yield advantage of Bt hybrids over non-Bt counterpart from the second set of field trials was 113 % with values ranging between 20 - 264 %. In general, farmers do not follow ETL based spray, instead they start spraying multiple pesticides when presence of pests are noticed in the field. Hence, the number of sprays, and quantity of pesticides used in the trials are significantly less than that from actual field situation values presented in Table 3.

Table 3 here

3:4 Estimation of welfare benefits from introducing Bt technology

However, the econometric implementation of the indirect profit function model explained earlier would require data that are difficult to obtain, particularly for recent innovations. Given that, Bt eggplant is not yet commercialized in the Indian market, the only available information sources are, farm survey, field trials, and secondary data sources.

Thus, our strategy for estimating total surplus generated by the introduction of Bt eggplant and its distribution among producers, consumers, and innovators is the following; a) estimate the expected technology induced supply shift b) estimate the expected Marshallian surplus distribution using the economic surplus model, and c) estimate the expected monopoly profit accruing to Mahyco using the estimated demand and WTP values for Bt hybrid eggplant.

We assume a closed economy model with linear supply and demand curves, and a parallel shift in the supply curve due to the introduction of new technology. Following Alston *et al*. (1995) the formulae for calculating the consumer and producer surplus are

$$\Delta CS = P_0 Q_0 (1 + 0.5Z\eta) \quad (9)$$

$$\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5Z\eta) \quad (10)$$

$$\Delta TS = P_0 Q_0 K(1 + 0.5Z\eta) \quad (11)$$

Where P_0 and Q_0 are initial equilibrium price and quantities, Z is the relative reduction in price due to new technology, K is the vertical shift in the supply function expressed as a proportion of initial price, and η is the absolute value of demand elasticity.

The relative reduction in price due to new technology

$$Z = K\varepsilon /(\varepsilon + \eta), \quad (12)$$

where ε is the elasticity of supply. Since Bt eggplant is not yet commercialized, an *ex ante* estimate of vertical shift in supply function can be calculated as

$$K = \left(\frac{E(y)}{\varepsilon} - \frac{E(c)}{1 + E(y)}\right) pA_t (1 - d_t) \quad (13)$$

where E(y) is the expected proportionate yield change per acre.

E(y)/ ε : converts the proportionate yield change to a proportionate gross reduction in marginal cost per quintal of output

E(c): Proportionate change in input costs/acre

E(c)/1+E(y): converts the proportionate input cost change per acre to a proportionate input cost change per quintal of output.

p: probability of success of technology, p is assumed to be 1 in the analysis

A_t : Adoption rate at time t

d_t: Depreciation rate of technology, d_t is assumed to be zero in the analysis

Since Bt eggplant is not yet available commercially, we combined the data from farm-level survey, field trials and other secondary sources for the welfare analysis. The parameters used in the welfare analysis are explained below.

3:5 Change in Pesticide Costs Per Acre

From the field trials data reported in Table 1, it could be seen that the average number of sprays on Bt plot is 39 % less than those on Non-Bt plots. Similarly, insecticide use on Bt plots is 52 % less than that of non-Bt plots. Data from the field trials show that, since Bt eggplant is targeted at a single pest, ESFB, farmers need to spray against other non-targeted pests such as, aphids, mites, white flies etc.. There was no difference in the number of sprays/ insecticide use against non-ESFB insects between Bt and non-Bt plots on the field trials. The data on pesticide use pattern from the field survey are presented in Table 3. The over-use of pesticides might be because farmers undertake most of the sprays on a preventive basis to ensure non-infested fruits during each harvest of the crop.

Comparing the results from field trials of Bt eggplant with the field/commercial market situation of Bt cotton in India, the savings in pesticide reduction has a similar pattern(Bennett et al. 2006, 59; Qaim et al. 2006, 48). Combining the information from field trials, farm survey, and performance of Bt cotton in India, the savings in pesticide expenditure due to the adoption of Bt hybrid eggplant was set at 40 % in the baseline scenario. A sensitivity analysis was conducted using 15 % as the lowest level and 65% as the maximum level of pesticide expenditure savings.

The current field trials were conducted for the evaluation of Bt hybrid eggplant only. The performance of Bt OPV might be different from that of Bt hybrid, due to the germplasm effect. However, according to the scientists working in the field, the behavior of Bt gene will be similar in both Bt hybrid & Bt OPV implying that same level of pest control could be achieved in Bt hybrid and Bt OPV. Hence, the savings in pesticide costs due to Bt OPV was also set at 40 % in the baseline scenario.

3:6 Seed Premium

The price increase of the Bt seed, which is related to the premium paid to the gene's patent owner (Monsanto) and the developer of the new variety (Mahyco), is difficult to estimate. In the United States, markups on transgenic varieties follow two strategies: a premium paid above the price of seeds of the variety, and a technology fee paid by the planted acre (Hareau et al. 2005, 229-246).The seed premium might be estimated based on per acre cost reduction in pesticides use (Couvillion et al. 2000,) with the assumption that the seed premium cannot be higher than the cost reductions achieved due to the use of Bt technology. Most of the surveyed farmers in Maharashtra (62%) knew about Bt technology due to the introduction of Bt cotton in 2002. The pricing strategy of Bt cotton which is priced four times the price of conventional hybrid seeds, clearly shows that the innovator could extract benefits derived from increase in yield, a variable not controlled by the technology *per se.*

Hence, to determine the upper level of seed premium, we estimate farmers' willingness to pay (WTP) for Bt technology using data from the farm-level survey. Given that most of the surveyed farmers knew about Bt cotton in India, and during the survey farmers were told about the potential benefits and risks associated with the technology, using the estimated WTP as seed markup (including seed premium and technology fee) is reasonable. The procedure used to estimate the WTP for Bt hybrid seed is detailed below.

A modified version of double bounded dichotomous choice contingent valuation approach (Kolady and Lesser 2005,) was used to elicit the WTP for potential adopters of Bt hybrid eggplant. As mentioned earlier, the first bid offered was Rs 400/10g packet for Bt hybrid seeds, and each of the surveyed farmers were asked to state their willingness to adopt Bt hybrid at this price. If the response was no, a lower bid was offered to assess their willingness to adopt Bt hybrid at the lower bid. After eliciting the information WTP for Bt hybrid, farmers were told about the development of Bt OPV seeds by public institutes. In order to capture any shift in farmers' expected behavior to Bt hybrid in the presence of Bt OPV, farmers were again requested to state their preference to Bt technology. The econometric procedure used to reflect the nature of the dependent variable (WTP) was constructed from the relevant survey question. Since the observed variable Y, has an ordered response (willingness to adopt Bt hybrid or not, at two bids) there are two possible procedures that could be exploited here. A standard ordered probit model could be used, as this captures the ordinal nature of the dependent variable (Wooldridge 2002,). However, it assumes that the threshold values delineating the different categories are unknown and the interval-coded nature of the data would thus be ignored in estimation. The second procedure explicitly takes into account the values of known thresholds governing the intervals (Daniels and Rospabe 2005, ; Reilly, Krstic, and Cominetta 2004, ; Wooldridge 2002,). Specifically, we are interested in estimating the WTP for Bt hybrid seed, i.e. E(Y*/X), where Y* is the WTP. Hence, the potential adopters of the Bt hybrid technology in the sample are divided into the following three categories based on their responses to WTP question,

1. Prob $(Y^* \geq Rs400) = P(Y^* \geq 400 / X) = I^{Y}$

$= (1 - \Phi(\frac{400 - X\beta}{\sigma}))$ where $\Phi()$ denotes the standard normal distribution (14)

Similarly

2. Prob $(Pbid \leq Y^* < Rs400) = I^{NY} = \Phi(\frac{400 - X\beta}{\sigma}) - \Phi(\frac{Pbid - X\beta}{\sigma}))$ (15)

3. Prob $(Y^* < Pbid) = I^{NN} = \Phi(\frac{Pbid - X\beta}{\sigma})$ (16)

Where I^{Y} (yes), I^{NY} (No, Yes), I^{NN} (No, No) are binary indicator choice variables for each farmer based on the above three categories. In addition to the interval-coded data, some responses are point data: either zero or some positive values. In order to make use of all these information, interval regression model is used for estimating the mean WTP. The likelihood for the interval regression, including both interval-coded and point data is

$$L = -\frac{1}{2}\sum_{j \in C}\{(\frac{Y_j - X\beta}{\sigma^2})^2 + \log 2\pi\sigma^2\} + \sum_{j \in R}\log\{1-\Phi(\frac{Y_{Rj} - X\beta}{\sigma})\} + \sum_{j \in I}\log\{\Phi(\frac{Y_{400j} - X\beta}{\sigma}) - \Phi(\frac{Y_{bidj} - X\beta}{\sigma})\}$$

$$+\sum_{j \in L}\log\Phi(\frac{Y_{Lj} - X\beta}{\sigma}) \qquad (17)$$

where observations $j \in C$ are point data; observations $j \in R$ are right-censored; observations; $j \in I$ are interval-coded data; and observations $j \in L$ are left censored. Y_{bidj} is the one step-down hypothetical bid price, Y_{Rj} is the right censored WTP, Y_{Lj} is the left censored WTP, and Y_j is the point data.

The mean WTP can be obtained using the estimated parameters from equation (17) at the mean level of the explanatory variables. Following Wooldridge (2002), the formula for mean WTP is E (Y*/X) = $\overline{X}\beta$

The results from WTP estimation for Bt hybrid eggplant under different scenarios presented to the farmers are given in Table 4.[5] On average farmers have a WTP of Rs 298/10 g packet (Rs2682/acre) assuming a seed rate of 80-90 g for hybrid eggplant. This is almost four times the average expenditure on hybrid seeds (Rs 75/10 g). Not surprisingly, early adopters of Bt hybrid are having a higher WTP of Rs 516/10 g. Our analysis suggests that farmers' WTP for Bt hybrid seeds decreases in the presence of Bt OPV seeds, albeit not very high. For the economic surplus analysis the estimated WTP of expected early adopters of Bt hybrid is set as the upper level (Rs 516/10 g), and a 40 % increase of the average price of hybrid seed is taken as the lowest level (Rs 105/10 g). The estimated WTP for the pooled (combining OPV and hybrid growers) sample is taken as the intermediate value (Rs 298/10 g).

[5] In scenario 1, WTP for Bt hybrid is elicited after explaining the expected yield and cost advantages associated with the technology. In scenario 2, farmers' willingness to adopt Bt hybrid was reassessed in the presence of Bt OPV.

Table 4 here

In the case of Bt OPV, due to the public-private partnership involved in the process, it is more likely that Bt OPV seeds would be priced on a non-profit basis. We also recognize that as opposed to hybrids, OPV growers may not replace their seeds annually, and hence the revenue from the seed sales is very limited. Based on the feed back from the pilot survey we used an open ended approach to estimate farmers' WTP for Bt OPV. Hence, farmers were asked to state their WTP for Bt OPV eggplant under the scenario presented to them and using their responses WTP was estimated. Results in Table 5, shows that farmers preferring only Bt OPV are having a higher WTP (Rs 106/50 g-Rs 212/acre)[6] while the average WTP for Bt OPV (Rs 62/50g) is almost four times the current expenditure on OPV seeds.[7] The estimated WTP by current OPV farmers is set as the upper level (Rs 111/50 g), and the current price of OPV seeds is taken as the lowest level (Rs 16/50 g). The estimated WTP from the pooled sample is taken as the intermediate value (Rs 62/50 g).

Table 5 here

Since introduction of Bt technology is expected to abate yield loss, a possible increase in labor requirement is expected. Previous studies on Bt cotton in India, reports a net increase in variable costs due to high seed premium and increased labor requirement in Bt cotton fields (Bennett et al. 2006, 59; Qaim et al. 2006, 48). However, since it is not clear whether the increased demand for labor would be met with family labor or hired labor, we assume that there will be no changes in costs except for seed premium and pesticide costs. The total change in variable costs due to the changes in pesticide cost and seed premium were calculated for each of the above scenario and the results are presented in Table 6.

Table 6 here

3:7 Yield Increase Per Acre

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[6] OPV seeds are sold in 50 g packets and the average cost is Rs 16/50 g.

[7] In general, OPV growers save and use the seeds from previous season crop, or exchange with neighboring farmers. The average seed rate from the farm-level survey for OPV eggplant was 380 g/acre.

As Bt technology is expected to provide early and efficient control of ESFB, it might lead to reduced yield loss. The yield advantage due to Bt technology would vary from farm to farm depending on the agronomic practices and climatic conditions. Subarmanian et al., 2000 analyzed the yield gap of major vegetables in India, and reported 56.5 tons/ha as the potentially achievable yield (PAY) for eggplant. The PAY was estimated as the 90 % of the best generally achievable yield in research stations and in adaptive trials. The study reported a yield gap of 40.7 tons/ha for eggplant which is the difference between PAY and the modal yield realized by farmers. In their study, the highest yield obtained at sample farmers' field was 21 tons/ha. The average yields obtained from our farm-level survey are 19 tons/ha, 13 tons/ha, and 16 tons/ha for hybrid eggplant, OPV eggplant, and the pooled sample respectively, and these values clearly indicate the extent of yield gap in the eggplant cultivation.

The comparative performance of Bt and Non-Bt eggplant from the field trials is reported in Table 2. On average, the yield of Bt eggplant exceeded those of non-Bt counterpart, popular hybrid check, and popular OPV by 117 %, 108%, and 192 % respectively. Since the field trials were managed by the company personnel it is possible that average technology gain will be somewhat lower in commercial agriculture. The increased yield of Bt hybrid over OPV, might be due to the germplasm effect of hybrid technology. According to the subject experts, early control of ESFB due to Bt technology increases the reproductive growth of the crop compared to non-Bt eggplant where early shoot damage may cause increased vegetative growth instead. The early control of the monophagous pest is important as it is very difficult to control the pest once infested and bored into the shoot or fruit for feeding. Even though, the data from the field trials are not conclusive, given the magnitude, the yield advantage of Bt eggplant in India is expected to be sizable.

Table 7 here

Table 7 reports the comparative figures from the performance of Bt cotton in India. The yield advantage attributed to Bt cotton, during the field trials was 80 % (Qaim and Zilberman

2003, 900-902), while a farm level study under commercial market situation reported only 33 % (41 % of field trial value) yield advantage over Non-Bt types (Qaim et al. 2006, 48). In a similar study on Bt cotton in the state of Maharashtra, India by Bennet *et al*. (2006), an yield advantage of 45 % and 63% were reported in the years 2002 and 2003 respectively. In order to capture the differences between actual field performance and the field trial performance, our strategy is to set 117 % as the maximum yield advantage that could be achieved due to Bt technology. Assuming that field trials reported the PAY level of Bt hybrid eggplant (220 quintals/acre) we set 23 % as the lowest level of yield advantage for Bt hybrid eggplant. We take 48 % and 80 % as intermediate values of yield advantages.

Since no field trial data was available for Bt OPV, the values for the analysis were taken based on the inputs from scientists working in the field. We set 60 %, 30 %, and 15 % as the maximum, intermediate and lowest values of yield advantages from adopting Bt OPV technology.

3:8 Adoption Rates

Adoption rates are crucial in the economic surplus analysis as it is one of the main determinants of total economic surplus. Building on the bivariate probit approach used in Kolady and Lesser 2005, we calculated the expected rates of adoption (discrete adoption) and the extent of adoption (proportionate area). Weighted averages of the adoption rates were taken to account for the low adoption rate of hybrids at the national level (30%) compared to the state level (60 %). Based on our analysis we set 10 % as the lowest level of adoption, 14 % as the intermediate level, and 34 % as the maximum level for Bt hybrid. The corresponding values for Bt OPV are 9%, 20 %, and 31 %.

3:9 Demand Elasticity

Subramaniam et al., (2000) analyzed the elasticity of demand for major vegetables in India. The absolute values ranged from 0.09 for lady's finger to 0.57 for peas with an estimated value of 0.56 for eggplant. Srinivasan (1987) estimated the demand elasticities for all vegetables (as a group) in India, and the absolute values were 0.21 for rural consumers and 0.40 for urban consumers. Nagarajan (1994) estimated the demand elasticity of vegetables in the state of Tamil Nadu as -0.57. Mani and Varadarajan (1989) reported a demand elasticity of -0.29 for eggplant in the state of Tamil Nadu. Based on the results from earlier studies, we select -0.56 as the demand elasticity for eggplant in India. For the sensitivity analysis, two other estimates, -0.20 and -0.40 were also chosen.

3:10 Supply Elasticity

The literature review did not provide any precise estimates for the supply elasticity of vegetables in India. Since there are no precise estimates of supply elasticity available for eggplant in India, following Alston et al., (1995) we set 1 as the supply elasticity of eggplant. Sensitivity analysis was conducted using 0.75 & 0.5 as two other estimates.

3:11 Prices

Using the data from National Horticulture Board, India, Mishra (2003) calculated the average wholesale price of eggplant for the year 1999 as Rs 491 per quintal,. In this study we use the average whole sale price of eggplant as Rs 531.3 per quintal for the period 2002-2005. This price was calculated using the data available from Directorate of Marketing and Inspection (DMI), Government of India. Even though in the local market OPV eggplant fetches slightly better price compared to hybrid eggplant, the national data available do not account for these differences.

3:12 Quantity

There is a marginal increase in the area under eggplant in India over the period 2002-2005. The average area for the period is 0.51 million hectares with an average yield of 16 tons/ha. The average production of eggplant in India for the period 2002-2005 was calculated to be 8145000 Mt (FAO STAT Database) and the quantity (Q_0) is set at this level in this study.

3:13 Monopoly Profits

The monopoly profit for the company was calculated as Q_{Bt} (P_{Bt}-c), where Q_{Bt}, P_{Bt} are the expected quantity (demand) and price of Bt hybrid seed, and c is the marginal cost of producing seed. Once a commercial transgenic variety has been created, the seed production process is identical for Bt hybrid and non-Bt hybrid seed production. Since we assumed that the current market for hybrid seeds is competitive, we further assume that the current seed market price represents the marginal seed production cost c. The expected Demand, Q_{Bt}, is calculated based on the expected adoption rates used in the study. The expected price of Bt seed, $P_{Bt,}$ is set at the seed premium estimated in the study. The profits used in the study are the expected gross revenue –no administrative, marketing, or regulatory costs were deducted. The issue of whether or not to deduct development cost from the firm's net return is not answered definitively in the literature. Here we assume that development costs are sunk and do not enter into the pricing decision.

3:14 Other Variables

Since two sets of field trials of Bt hybrid eggplant were over in India during 2004-2006, the probability of success of Bt eggplant p, in India is set as 1 in the economic surplus analysis. Since our study focuses on the initial years of introduction of Bt eggplant in India, the depreciation rate for the period is set at 0%.

4:1 Results:

Results from the welfare analysis of adoption of Bt hybrid eggplant are presented in Table 8. The figures in the first row of table are the results from the baseline scenario of Bt hybrid adoption in the framework of imperfect market competition. The results indicate that with a modest estimate of expected of yield advantage (48 %), and adoption rate (10 %), the expected change in total surplus generated is fairly large. The distribution of benefits among producers, consumers, and the company indicates that consumers gain maximum (60 %) of the change in total surplus. Results from the welfare analysis under perfect competition (second row in table 8) show that the estimated change in total surplus generated increases by 42 % with the assumption of perfect competition in the input markets. This result confirms the earlier findings (Moschini and Lapan 1997, 1229-1242) that the conventional measures that apply to publicly produced innovations will not be appropriate for assessing the welfare benefits associated with innovations introduced by suppliers of agricultural inputs.

Table 8 here

Due to the *ex ante* nature of the study and also due to the uncertainty of the parameters selected for the analysis, sensitivity analysis was conducted to assess the robustness of the results. The results in Table 9 are obtained by varying the yield advantages and savings on pesticide expenditure. The most conservative scenario presented in Table 9, with 23% yield advantage and 15% savings on pesticide expenses show that farmers' share of the total surplus generated could be as low as 27%, and the private company could gain as high as 26% of the potential benefits created. Our analysis showed that if the savings in pesticide expenditure and yield advantages are low and seed premiums are high (300 % increase in seed price compared to that of hybrid seeds), the company could extract most of the benefits attributed to the technology. The most optimistic scenario presented in the table shows that farmers' could gain 35% of potential benefits created due to the adoption while company's profit share shrinks to 3%.

Table 9 here

Since Bt hybrid eggplant is not yet commercialized, and no market price is available for the Bt hybrid seeds, a sensitivity analysis was conducted with different estimated values of seed premium and respective adoption rates to estimate its effect on the size and distribution of the economic benefits from adopting Bt technology in India. The results are presented in Table 10. A seed premium of Rs 105/10 g (40% higher than the conventional hybrid seed price) would result in a higher economic surplus, relative to all other categories presented in the table, while company's share in the total surplus is negligible under such a scenario. Our analysis showed that the company's profit increases with increase in seed premium upto Rs 540/10 g, and then decreases due to the drastic reduction in adoption rate. As shown in Table 10, even though company increases its profits with an increase in seed premium upto a certain level, the total change in the economic surplus generated and producers' share in it decreases significantly due to the less adoption rate resulting from higher seed premium. We find that a 390 % increase in seed premium (from Rs 105/10 g to Rs 515/10 g) results in a 300 % increase in profit for the company, while the profit decreases for a price above Rs 540/10 g. This shows that the company profits and seed premium are not linearly related. Company has quite a wide range of prices to select from which could result in increased adoption rate without affecting company profits significantly. Given that most of the vegetable farmers in India are having small holdings, an affordable price might lead to increased diffusion of the technology. Results from the above analysis showed that an increase in seed price could significantly reduce the adoption rate, and hence the total welfare generated whereas its influence on distribution of welfare benefits is limited. Seed premium influences both the total surplus generated and its distribution among different stakeholders.

Table 10 here

Results from the field trials of Bt hybrid eggplant in India (2004-2006), indicate that the major share of the benefits from adopting Bt technology comes from the increased yield, a trait not directly controlled by the technology. Hence, as in the case of Bt cotton in India, it is possible for the company to capture the full benefits from the pesticide savings and also a part of the yield advantages associated with the technology. Given that Bt technology is already licensed to Mahyco by Monsanto, it is unclear at this point whether the private company Mahyco has to pay any royalty to Monsanto for developing Bt hybrid eggplant using Monsanto's Bt construct. This could also factor in the final pricing decision of Bt hybrid eggplant.

Results from the sensitivity analysis of demand and supply elasiticities are presented in Tables 11 and 12. As shown in Table 11, a relative inelastic price elasticity of supply (.5) generates more economic surplus than a unitary price elasticity of supply. The producers' share increases with a relatively inelastic price elasticity of supply. A 1% increase in the elasticity of supply results in about .66 % decrease in the total economic surplus generated. Thus the results from Table 11 indicate that the total surplus generated and its distribution is sensitive to the changes in the price elasticity of supply. The results presented in Table 12 indicate that the total surplus generated is less sensitive to the price elasticity of demand, while the distribution of benefits is more sensitive to changes in the values of demand elasticity. Our analysis clearly shows that, consumers always gain from an innovation, and farmers' gain depend on the price elasticity of demand for the final product.

Tables 11 and 12

4:2 Welfare benefits from adopting Bt OPV eggplant

Since public institutes are involved in the development and release of Bt OPV, we analyzed the welfare benefits from the adoption of Bt OPV eggplant using the conventional framework illustrated in Alston et al. 1995. As shown in Table 13, the total change in economic surplus generated under the baseline scenario is fairly large. As in the case of Bt hybrid, consumers' gain maximum of the total surplus generated (64%). Similar pattern of consumers' and producers' share was reported by Mishra 2003, in an *ex ante* economic impact assessment of Bt eggplant in India. Since Bt OPV is expected to be priced on a no-profit basis by the public sector, the producers' and consumers' share in the total surplus generated is high compared to that of Bt hybrid eggplant. Our results show that in the case of Bt OPV, most of the benefits generated out of savings from reduced sprayings due to the Bt technology is transferred to producers and consumers. Results from the sensitivity analysis of changes in adoption rate, yield advantage and pesticide savings are presented in Tables 13 and 14. As explained in the case of Bt hybrid eggplant increased adoption rate, yield advantages and pesticide savings increase the total welfare generated.

Tables 13 and 14

It should be noted that India is considered as one of the centers of origin of eggplant. Farmers' varietal preference varies from village to village. Our data and analysis clearly show that many farmers (OPV growers) are willing to adopt Bt OPV provided their varietal preference criteria are met. Hence the results from the welfare analysis of Bt OPV must be interpreted with caution, as it is not clear at this point by what mechanism public institutes are going to address the varietal preference issue. Since selection of right varieties for developing Bt OPV is important for increasing the adoption rate of Bt OPV, public institutes face a serious challenge in selecting appropriate varieties.

4:3 Is it feasible to provide GM crops on preferential terms to small farmers?

Our analysis shows that the welfare benefits from adopting Bt technology are high, and our results also indicate the economic importance of developing Bt OPVs. But one of the key questions is whether pricing of Bt OPV on non-profit basis makes it a competitor to Bt hybrid or are they complementary to each other? Here, we assess the economic feasibility of providing Bt technology on preferential terms to eggplant (OPV) growers.

With the introduction of Bt eggplant, farmers could select from one of the four options: Bt hybrid, Bt OPV, both Bt hybrid and Bt OPV, and no Bt technology. The results from the bivariate probit analysis of adoption of Bt hybrid eggplant used in the welfare analysis show that with the introduction of Bt OPV some of the farmers decided to adopt Bt hybrid might shift to Bt OPV once it is made available. As reported in Kolady and Lesser 2005, most of those willing to adopt Bt hybrid in the first year of introduction of Bt hybrid will continue to grow Bt hybrid even in the presence of Bt OPV. As shown in Tables 15 and 16, the production characteristics of early adopters of Bt hybrid, those willing to grow Bt hybrid even in the presence of Bt OPV, and hybrid growers are similar. Not surprisingly, the production characteristics of OPV growers and those willing to adopt Bt OPV are similar. These findings imply that most of the expected adopters of Bt hybrid are hybrid growers while most of the expected adopters of Bt OPV are OPV growers. Both hybrid (55 %) and OPV growers (45 %) are included in the late adopters of Bt hybrid, hence it is expected that some of these farmers might shift to Bt OPV once made available due to its low seed price. As the seed premium depends on the trait value of the technology (the expected benefits by reducing pesticide application, and by abating yield loss) Bt hybrids would be priced higher than Bt OPVs. The yield advantage of hybrids over OPV was the main reason for most of the surveyed farmers to adopt hybrid eggplant. Thus the yield advantage associated with the Bt hybrid over non-Bt hybrid and OPV eggplant might act as an incentive for the current hybrid growers to adopt Bt hybrid over Bt OPV. As the area under hybrid eggplant is increasing over the years it might be possible that some of the Bt OPV adopters shift to Bt hybrid due to the better performance of the latter, while chances of a reverse shift are limited. However, introduction of Bt OPVs by public sector might prevent private companies from charging a very high premium for Bt hybrid seeds. Further, since Bt eggplant is the first GM vegetable crop to be commercialized in India, the public-private partnership involved in the development program might increase the acceptance of the technology among farmers, consumers and other stakeholders at the national level. The strategic alliance of the company with other national institutes (in Philippines and Bangladesh) would also help to increase the acceptance of the technology at the regional level.

Tables 15 and 16 here

5 :Conclusions

Even though the area under hybrid eggplant in India is small, enforcement of IPRs and presence of an organized market promotes private investment in the R&D of Bt hybrid eggplant. As the private companies are interested in Bt hybrids only, the public private partnership emerged in the development of Bt OPV addresses the issue of economic access to technology by resource-poor farmers. Our results show that the potential welfare benefits from adopting Bt technology is very high. However these benefits and their distribution among producers, consumers and the company are sensitive to the parameter values such as supply and demand elasticities, adoption rates, and seed premium. Over all, our analysis showed that consumers gain maximum (60 %) of the total surplus generated due to the introduction of the technology.

In the case of Bt hybrid, seed premium is a major factor determining adoption rate and hence the total surplus generated and its distribution. Our results suggest that as in the case of Bt cotton in India, the company could extract most of the benefits associated with the pesticide saving nature of the technology. Even though the company has a wide range of prices to select from (Rs 105/10 g to Rs 540/10g), marketing Bt hybrid seeds at affordable prices increases the total surplus generated.

Magnitude of the potential benefits that could be generated out of introducing Bt OPV is huge. Our data and analysis clearly show that many farmers (OPV growers) are willing to adopt Bt OPV provided their varietal preference criteria are met. Since India is considered as one of centers of origin of eggplant, large number of traditional varieties with different morphological characteristics is present in the country. Hence, the results from the welfare analysis of Bt OPV must be interpreted with caution, as it is not clear at this point by what mechanism public institutes are going to address the varietal preference issue.

We find that providing Bt OPV on preferential terms to resource-poor farmers would not be detrimental to the firm's interest. Even though, due to the low price of Bt OPV some of the farmers decided to adopt Bt hybrid might shift to Bt OPV, most of the hybrid growers would prefer Bt hybrid over Bt OPV. The yield advantages attributed to the Bt hybrid technology might out weigh the low price attributes of Bt OPV. Thus, these two technologies are targeted at different groups of farmers. Further, development of Bt OPV by public institutes might increase the acceptance of Bt technology among farmers and consumers. As the area under hybrid eggplant is increasing over the years, better performance of Bt eggplant in farmers' fields would result in increased area under Bt eggplant. The size and distribution of benefits would change as more Bt eggplant varieties are made available, but results from our study provide an initial empirical estimate of potential benefits arising from the introduction of Bt eggplant in India.

References

Allam, M. A., Kameswara P. Rao, and Krishnamurthy B. H. Rao. 1982. *Chemical control of brinjal shoot and fruit borer, Leucinodes orbonalis Guen.with newer insecticides*.

Alston, Julian M., Norton, George W., and Pardey, Philip G. 1995. *Science under scarcity: Principles and practice for agricultural research evaluation and priority* *setting.* Food Systems and Agrarian Change series. Ithaca and London: Cornell University Press in cooperation with the International Service for National Agricultural Research.

Bennett, R., U. Kambhampati, S. Morse, and Y. Ismael. 2006. Farm-Level Economic Performance of Genetically Modified Cotton in Maharashtra, India. *Review of Agricultural Economics* 28, 59.

Cork, A., et al. 2003. Pheromones and Their Application to Insect Pest Control- a Review. *Bangladesh Journal of Entomology* 13, 1-13.

Couvillion, W. C., F. Kari, D. Hudson, and A. Allen. 2000. A Preliminary Economic Assessment of Roundup Ready Soybeans in Mississippi. *Mississippi State University.Research Report* 5, .

Daniels, R. C., and Rospabe, B. Estiamting Earning Function from Coarsened Data by an Interval Censored Regression Procedure. in Development Policy Research Unit [database online]. 20052005]. Available from http://www.commerce.uct.ac.za/dpru/WorkingPapers/PDF_Files/WP_05-91.pdf.

Dhandapani, N., U. R. Shelkar, and M. Murugan. 2003. Bio-Intensive Pest Management in Major Vegetable Crops: An Indian Perspective. *Journal of Food, Agriculture & Environment* 1, no. 2:330-339.

FAO. 2002. *What Should be the Role and Focus of Biotechnology in the Agricultural Agendas of Developing Countries ?* Vol. 8. FAO.

Hareau, Guy G., George W. Norton, Bradford F. Mills, and Everett Peterson. 2005. Potential Benefits of Transgenic Rice in Asia: A General Equilibrium Analysis. *Quarterly Journal of International Agriculture* 44, no. 3:229-246.

James, C. 2005. Global status of commercialized Biotech/GM crops. *ISAAA Briefs*.

Kataria, A. S. Development of F1 Hybird in Vegetable Crops and the Availability in Public and Private Sector. 20052005]. Available from http://www.seedassociationofindia.com.paperbysai.asp.

Kolady, D., and Lesser, W. 2005. *Adoption of Genetically Modified Eggplant in India: an Ex Ante Analysis.*Rhode Island, USA ed. USA: American Agricultural Economic Association, 2005.

Moschini, G., and H. Lapan. 1997. Intellectual Property Rights and the Welfare Effects of Agricultural R&D. *American Journal of Agricultural Economics* 79, no. 4:1229-1242.

Moschini, Giancarlo, Lapan,Harvey Affiliation: IA State U., IA State U Collection Au: Galizzi,Giovanni, and Venturini, Luciano. 1999. Intellectual Property Rights and the

Welfare Effects of Agricultural R&D. In . Contributions to Economics. Heidelberg: Physica.

Qaim, M., A. Subramanian, G. Naik, and D. Zilberman. 2006. Adoption of Bt Cotton and Impact Variability: Insights from India. *Review of Agricultural Economics* 28, 48.

Qaim, M., and D. Zilberman. 2003. Yield Effects of Genetically Modified Crops in Developing Countries. *Science* 299, no. 5608:900-902.

Reilly, B., Krstic, G. and Cominetta, M. Purchasing from Informal Markets: Evidence from Serbia. in University of Sussex [database online]. U.K., 20042005]. Available from www.sussex.ac.uk/Units/economics/qm2/sjh.doc.

Subramania, S. R., Vardarajan, S. R., and Asokan, M. 2000. India. In *Dynamics of Vegetable Production, Distribution, and Consumption in Asia*, edited by M. Ali. Thailand: The World Vegetable Center, AVRDC.

Vavilov, N. I. 1951. *The Origin, Variation, Immunity and Breeding of Cultivated Plants: Selected Writings.*Chronica Botanica Company.

Wooldridge, J. M. 2002. *Econometric analysis of cross section and panel data.*MIT Press Cambridge, Mass.

Table 1: Summary of pesticide use on Bt and Non-Bt eggplant field trial plots (N=10)

Category	**Sprays(#)**			**Quantity(liters/acre)**		
	ESFB	**Other pests**	**total**	**ESFB**	**Other pests**	**total**
Bt hybrid	0	3.3(1.8)	3.3(1.8)**	0	2.6(5.5)	2.6(5.5)**
Non-Bt	2.1(1.9)	3.3(1.8)	5.4(2.8)**	2.8(2.5)	2.6(5.5)	5.4(5.2)**

Standard Deviations are given in parentheses

** mean values are significantly different at 1 % level between Bt and non-Bt plots

Table 2: Summary of crop yields from Bt eggplant field trials (2004-2005)

Category	Yield (Quintals/acre)
Bt hybrid	220.8
Non-Bt hybrid	101.9
Competitor's hybrid	106
Popular OPV	75.5

Table 3: Pesticide Use and Expenses incurred for eggplant cultivation

Category	Sprays(#)	Quantity(L/acre)	Expenses(Rs/acre)
Hybrid	35.5(21.5)**	28.4(22.9)**	13236(10051)**
OPV	12.3(9.7)**	10.8(12.9)**	5228(7041)**
Pooled sample	26.8(21.2)	21.8(21.5)	10245(9828.7)

Standard Deviations are given in parentheses

Table 4: Summary of Results from WTP estimation of Bt hybrid

Category	WTP (Rs/10gm)
When Only Bt hybrids are available	
Expected adopters of Bt hybrid in the first year	516(234)
Expected adopters including late adopters	490(220)
Scenario 2(Bt OPV is also available)	
Expected adopters of Bt hybrid	500(233)
Pooled sample(N=247)	298(330)

Table 5: Summary of Results from WTP estimation of Bt OPV

Category	**WTP (Rs/50 g)**
WTP of current OPV growers	111(33.3)
WTP of expected adopters of Bt OPV	106(33.7)
Pooled sample	62(52)

Standard deviations are given in the parentheses

Table 6: Estimated changes in variable costs(VC) due to Bt technology

Estimated seed premium(Rs/10gm)	**Savings in pesticide expenses (%)**	**Change in VC (%)**
298	**40**	**-15**
298	**65**	**-40**
298	**15**	**+9**
105	**40**	**-32**
515	**40**	**+4**

Table 7: Results from the previous studies on yield advantages of Bt cotton in India

Category	**Yield from field trials(tons/ha)**	**Yield from Commercial market conditions(quintals/acre)**		
		Study1	**Study2**	**Study3**
Bt hybrid	1.5	8.83	9.10	6.59
Non-Bt counterpart	.83			
Popular check	.80			
Non-Bt types		6.09	5.59	4.9

Study 1- by Bennet et al., 2006(season 2002), Study 2- by Bennet et al., 2006(season 2003), Study 3- by Qaim et al., 2006

Table 8: Results from Economic surplus Analysis of Bt hybrid eggplant in India

Category	Producer surplus(Rs)	Consumer surplus(Rs)	Company Profit	Total(Rs)
Bt hybrid(baseline)	1,104,254,985(59%)	1,971,883,901(33%)	251,976,406(7%)	3,328,115,292
perfect competition	1,697,328,935	3,030,944,526		4,728,273,461

Table 9: Sensitivity analysis with expected changes in yield benefits and pesticides savings for Bt hybrid eggplant

Yield change (%)	Pesticide savings (%)	TS(Rs)	PS(Rs)	CS(RS)	Profit(Rs)
117	15	4,543,722,200	1,540,626,695(34)	2,751,119,099(61)	251,976,406(5)
117	40	6,897,375,623	2,385,527,924(35)	4,259,,871,293(62)	251,976,406(3)
117	65	9,393,902,260	3,281,716,973(35)	586,020,880(62)	251,976,406(3)
80	15	3,044,498,080	1,002,443,678(33)	1,790,077,996(59)	251,976,406(7)
80	40	4,971,262,243	1,694,102,608(34)	3,025,183,229(61)	251,976,406(5)
80	65	7,009,136,253	2,425,647,124(35)	4,331,512,722(62)	251,976,406(3)
48	15	1,762,073,705	542,086,209(31)	968,011,088(56)	251,976,406(13)
48	40	3,328,115,292	1,104,254,985(33)	1,971,883,901(60)	251,976,406(7)
48	65	4,9802,49,867	1,697,328,935(34)	3,030,944,526(61)	251,976,406(5)
23	15	7,693,452,284	185,722,162(27)	331,646,717(47)	251,976,406(26)
23	40	2,059,044,505	648,691,113(32)	1,158,376,987(57)	251,976,406(11)
23	65	3,416,876,160	542,086,209(33)	968,011,088(60)	251,976,406(7)

Figures in parentheses are percentages.

TS-total surplus, PS-producer surplus, CS-consumer surplus, TS

Table 10: Results from the Sensitivity analysis with changes in adoption rates &seed premiums for Bt hybrid eggplant

Seed premium(Rs)	Adoption rate (%)	TS(Rs)	PS(Rs)	CS(RS)	Profit(Rs)
105	34	14,961,990,909	5,329,725,090(35.6)	9,517,366,231(63.6)	114,899,589(.8)
105	14	5,961,700,558	2,123,599,234(35.6)	3,792,141,489(63.6)	45,959,835(.8)
298	27	9,163,017,078	3,044,557,274(33)	5,436,709,419(60)	681,750,384(7)
298	10	3,328,115,292	1,104,254,985(59)	1,971,883,901(33)	251,976,406(7)
515	14	3,281,712,589	1,651,498,454(29)	924,839,134(52)	705,375,000(19)
515	6	1,381,758,744	394,731,344	704,877,400	282,150,000

Table 11: Results from sensitivity analysis of supply elasticity for Bt hybrid eggplant

Supply elasticity	**TS(Rs)**	**PS(Rs)**	**CS(Rs)**	**Company profit(Rs)**
1	3,328,115,292	1,104,254,985(59)	1,971,883,901(33)	251,976,406(7)
.75	4,033,774,211	1,616,646,390(40)	216,515,415(54)	251,976,406(6)
.5	5,446,861,123	2,744,467,398(50)	2,450,417,319(45)	252,976,406(5)

Table 12: Results from sensitivity analysis of Demand Elasticity for Bt hybrid eggplant

Demand elasticity	**TS(Rs)**	**PS(Rs)**	**CS(Rs)**	**Company profit(Rs)**
-.56	3,328,115,292	1,104,254,985(59)	1,971,883,901(33)	251,976,406(7)
-.40	3,320,303,647	876,664,926(27)	2,191,662,315(66)	251,976,406(7)
-.20	3,307,609,725	509,272,219(15)	2,546,361,099(77)	251,976,406(8)

Table 13: Results from sensitivity analysis for Bt OPV eggplant

Yield change (%)	Pesticide savings (%)	TS(Rs)	PS(Rs)	CS(RS)
30	40	3,132,050,991	1,124,325,997(36)	2,007,724,994(64)
30	15	1,840,450,483	660,674,532	1,179,775,951
30	65	4,384,491,317	1,573,919,960(36)	2,810,571,357(64)
15	15	1,172,104,476	420,755,452 (36)	751,349,023(64)
15	40	2,307,864,076	828,464,027 (36)	1,479,400,049(64)
15	65	3,407,978,102	1,223,376,755(36)	2,184,601,347(64)
60	15	3,187,987,758	1144,405,862 (36)	2,043,581,896(64)
60	40	4,796,599,708	1,721,856,305(36)	3,074,743,402(64)
60	65	6,359,807,907	2,283,007,966(36)	4,076,799,940(64)

Table 14: Results from sensitivity analysis Bt OPV (adoption rate)

Adoption rate (%)	TS(Rs)	PS(Rs)	CS(RS)
9	3,132,050,991	1,124,325,997(36)	2,007,724,994(64)
20	7,305,905,679	2,622,632,808(36)	4,683,272,871(64)
31	11,502,246,626	4,129,011,609(36)	7,373,235,017(64)

Table 15: Cost of Production details of eggplant for different groups of eggplant growers

Category	Hybrid growers	OPV growers
Insecticide expenses (Rs/acre)	13236(10051)	5228(7041)
Total variable costs (Rs/acre)	28079(14616)	14030(11981)
Gross returns (Rs/acre)	51001(31234)	36078(25767)
Net returns(Rs/acre)	22922(29516)	22502(24501)
Yield (Quintals/acre)	75(40)	51(28)
Number of observations	156	93

Table 16: Cost of Production details of eggplant for expected adopters of Bt eggplant

Category	Early adopters of Bt hybrid	Late adopters of Bt hybrid	Adopters of Bt hybrid when Bt OPV available	Bt OPV adopters
Insecticide expenses (Rs/acre)	13518(10903)	12552(6863)	13653(10341)	5149(5520)
Total variable costs (Rs/acre)	28242(16287)	27141(11047)	29331(15084)	14669(10311)
Gross returns (Rs/acre)	49264(32689)	43055(22502)	49765(32117)	37369(27544)
Net returns(Rs/acre)	21022(28749)	15914(21551)	20434(28309)	23432(24228)
Yield (Quintals/acre)	69(40)	66(28)	70(33)	57(44)
Number of observations	108	33	104	62

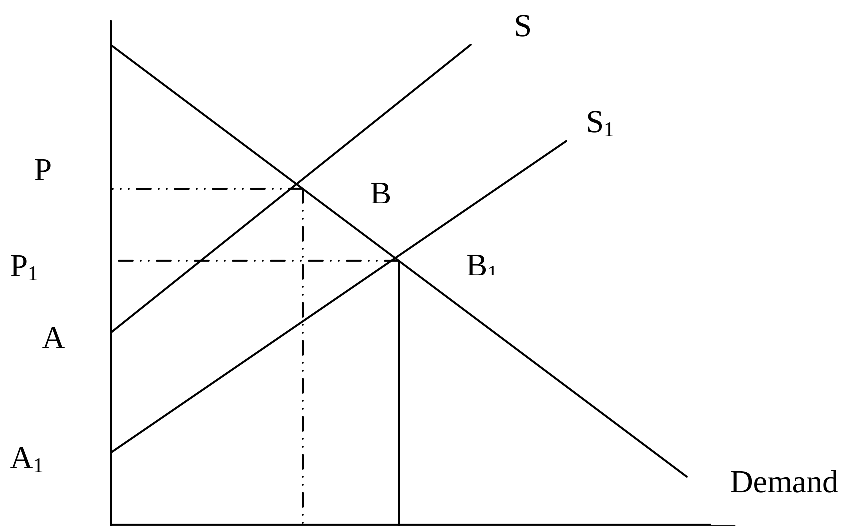

Fig. 1 Change in total surplus with technological change

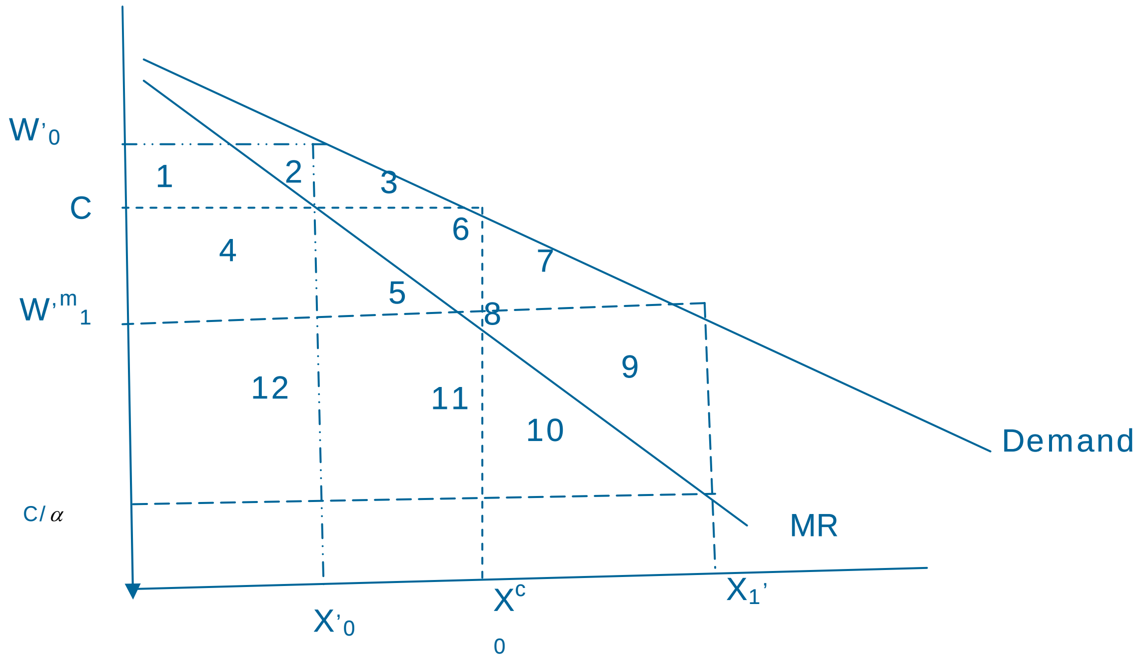

Fig.2: Marshallian Surplus and monopolist's profit in the input market