Bt Eggplant in Bangladesh Increases Yields and Farmers' Incomes, and Reduces Pesticide Use

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Genetically engineered (GE) Bt eggplant was introduced to Bangladesh in 2013 and by 2017, 18% of eggplant growers have adopted it. Our study, based on a survey of 481 farmers, indicates that adoption of Bt eggplant increases yield and profits. Farmers receive higher prices for GE eggplant compared to other varieties. The technology also reduced pesticide applications and thus has the potential to improve health and reduce environmental damage of farming. The level of adoption is likely to increase, and the success of Bt eggplant may lead to the adoption of GE varieties in other vegetable crops.

Genetically engineered (GE) crop varieties were introduced in the early 1990s and have been widely adopted in the production of feed (corn, soybeans) and fiber (cotton) crops. GE has seldom been adopted with crops used directly for human consumption, including grains like wheat and rice and especially vegetables and fruits. There is a wide variety of evidence that GE crops do not present more risk than traditional crops. Furthermore, the major beneficiaries of such crops are likely to be producers and consumers in developing countries.

The barriers to the adoption of GE crops are regulatory, as well as a perception of strong consumer resistance, expressed in low willingness-to-pay for the crops. This paper presents the results of an important case study of the adoption and impacts of a GE food variety: Bt eggplant (brinjal), which was developed by South Asian scientists and introduced in Bangladesh in 2013. This paper provides background on Bt eggplant and Bangladesh, an assessment of the impacts of Bt eggplant, and a discussion of the challenges of adoption.

Background

Eggplant is a diet staple in Bangladesh, it ranks third after potato and rice among vegetables in the country in quantity consumed, and thus it is important for food security. About 150,000 farmers grow eggplant on approximately 50,000 hectares in two seasons: winter and summer. The productivity of eggplant farming in Bangladesh has been relatively low because of insect damage that reduced yield by two-thirds, despite efforts to introduce insecticide and cultural practices. Eggplant productivity could be raised substantially if the crop's major pests could be managed effectively.

Due to heavy infestations of multiple pest species, crop production has relied intensively on insecticides. This has led to economic losses and human health damage. Research efforts by the Bangladesh Agricultural Research Institute (BARI), with the support of Maharashtra Hybrid Seeds Company Private Limited (Mahyco), developed Bt eggplant as a long-term solution to the pest problem. Bt eggplant is a genetically modified eggplant that carries an additional gene providing built-in protection against pests. With the introduction of Bt eggplant in 2014, Bangladesh became the 29th country to grow a genetically-engineered crop. By 2017, over 27,000 farmers were growing Bt eggplant in Bangladesh.

Currently, farmers apply insecticides on a daily or twice-daily basis up to 140 times per season. Continuous use of pesticides becomes ineffective due to pest resistance to the insecticide. Furthermore, heavy use of chemical insecticides results in pollution and health hazards to both producers and consumers. In October 2013, the government of Bangladesh released four genetically modified varieties of Bt eggplant for seed production and initial commercialization.

The South Asia Eggplant Improvement Partnership initiated the development of Bt eggplant with support from the U.S. Agency for International Development (USAID). BARI then introduced the Bt trait into commercially popular, open-pollinated eggplant varieties in Bangladesh. This allowed the establishment of a diversity of local varieties with GE traits. Out of the nine popular varieties that were modified with Bt event EE-1, four were approved for commercial cultivation in October 2013.

The cultivation of Bt eggplant started in spring 2014 by 20 small eggplant farmers in 2 hectares of land in four representative districts—Gazipur, Jamalpur, Pabna, and Rangpur. The appropriate varieties were selected for each district. BARI played the key role as the only organization in the first three years (2013-2015) to disseminate the new technology to farmers on a small scale. BARI's program led to 108 farmers in 2014-15 season, and 250 farmers in 2015-16 season to adopt the new technology. Extension agents in the Department of Agricultural Extension (DAE) started to disseminate the new variety in 2016, followed by the Bangladesh Agricultural Development Corporation (BADC) in 2017.

Initially, the dissemination was directed by the government and extension (DAE) and led 6,000 farmers to adopt the Bt eggplant, the development corporation (BADC) dissemination activities significantly expanded adoption

Table 1. Market Price (Bangladeshi Taka) Information

	Bt	Non-Bt	Bt Premium
Wholesale	15.45	11.7	32%
Retail	28.6	22.35	28%
Mark up	13.5	10.65	27%

and led an additional 19,430 farmers to adopt Bt eggplant. In total, 27,012 farmers have adopted the new variety by the spring 2018 season, and there is still potential for much higher adoption rates, as approximately 150,000 farmers grow eggplant in the country.

The success of Bt eggplant has led the government of Bangladesh to sanction the field testing of three other genetically engineered crops—a GE disease-resistant potato, Bt cotton, and golden rice. Other crops are undergoing research as well, such as BARI's work on a GE tomato resistant to the leaf curl virus, Dhaka University's trial to develop salt-tolerant rice, and Dhaka University's research on GM fungal-resistant peanuts, lentils, chickpeas, and mung beans.

Despite this interest in GE crop varieties, there are very few studies that assess the effectiveness of Bt eggplant in Bangladesh, and those that exist are mostly based on experimental plots. None so far evaluates the effectiveness of Bt eggplant using farmers' field data collected by farmers cultivated in a non-experimental set-up. We bridge this gap by evaluating the cost-effectiveness of Bt eggplant using farm-household survey data from Bangladesh.

Assessment of Bt Eggplant in Bangladesh

We conducted a survey of 500 farmers in 8 districts of Bangladesh—Comilla, Mymensingh, Jamalpur, Sherpur, Kushtia, Meherpur, Gazipur and Narsingdi. The districts were chosen intentionally to represent areas where Bt farmers are available. Farmers in our survey adopted the Bt eggplant by purchasing seed from stores, rather than receiving seed for free from a government program. Among 500 farmers surveyed, 301 grew Bt eggplant. Among Bt farmers, 18 grew both Bt and non-Bt varieties. In order to estimate the differential outcomes, we used the farmers who grew either only Bt or non-Bt varieties. This led our final sample size to be 482.

The average age of farmers in our survey is 42.89 years, with 4.22 years of schooling, 5.25 total members in the family, 0.57 acre vegetable farm size, 93% of whom are married, 79% of whom are members in a community organization, and with an average home distance of 2.64 kilometers (km) away from local bazaar. There is no statistical difference on observable characteristics between adopters and non-adopters.

We first identified the factors that affect adoption. We found an increased adoption of Bt eggplant among farmers over time, both in terms of number of adopters and in acreage. We estimated the factors that increase the likelihood of increased adoption of Bt eggplant, and find that large farmers with mostly grains and rice have a lower likelihood of adoption than larger vegetable farms. Credit is very important and farmers with access to a bank, and in particular with a bank account at the local commercial bank, are more likely to adopt. Location also matters and farmers mostly living near local markets and having nearby Bt eggplant plots are more likely to adopt. Finally, the likelihood of adoption increases with age and with membership in a community.

In addition to a farmer survey, we also collected data on the market prices of Bt and non-Bt eggplant at both retail and wholesale levels. The results in Table 1 show that Bt prices are higher than non-Bt prices at both the retail and wholesale levels. A higher wholesale price for Bt eggplant suggests that farmers are receiving higher prices for the Bt variety while higher retail prices for Bt eggplant might indicate that consumers are willing to pay more for Bt varieties. Furthermore, the retailer receives a higher premium (difference between wholesale and retail price) for Bt varieties. The results suggest around a 30% price premium at all levels for the Bt varieties.

The major reasons for higher prices for Bt varieties mentioned by the respondents are that they look fresher, they have fewer blemishes, and most importantly, they do not have holes that are present in non-Bt eggplants from pest invasions. This finding contrasts with most of the previous literature, which presumes that consumers are willing to pay less for GE varieties than non-GE varieties. Here, we find that once GE products have preferred observable characteristics, they obtain a positive premium. Better product quality trumps some of the presumed objections to GE among the buyers.

Our sample covers eggplant farming on 129 acres of land for both Bt and non-Bt varieties (see Table 2). The production data show that yield per acre of land is higher by 65% for Bt varieties than non-Bt ones. The adoption of Bt eggplant seems to increase yield, but also increases total cost of production (Table 3). The increase in total cost is due to the higher price of seed and higher labor costs associated with high yields. However, adoption of Bt eggplant reduces average chemical

Table 2. Comparative Production Outcome

Type	Yield (ton)	Total Area (acre)	Yield (Tons/acre)
Bt	844.13	67.85	12.44
Non-Bt	461.54	61.13	7.55
Total	1305.67		65% increase

pesticides cost per acre. More importantly, not only are the chemical pesticide costs lower for Bt varieties than non-Bt ones, but the pesticide costs as the percentage of total cost are much lower (15%) for Bt eggplant than that of non-Bt ones (24%). Controlling for the major pests responsible for substantial yield requires pesticide use. Focusing on farming practices, average spraying per week for Bt varieties was found to be 32% lower than that for non-Bt eggplant cultivation (t=17.47).

The outcomes reported above are based on average outcomes in the sample. To further assess these outcomes, we apply econometric models to estimate the impact of Bt eggplant variety adoption on its profitability and to identify variables that are statistically significant. While investigating the source of increased profit, our results show that adoption of Bt eggplant raises yield by 17%–26% compared to non-Bt varieties. We find that Bt farmers spray 1–2 times less per week compared to non-Bt farmers, and thus Bt eggplant farmers incur between 52%–98% lower pesticides cost per acre compared to that associated with non-Bt eggplant farming.

While having lower pesticide costs, Bt eggplant farmers have higher seed and labor costs (relating to the higher yield). Therefore, there is no statistically significant difference in cost of farming per unit of land between Bt and non-Bt varieties of eggplant. But with higher yields of Bt eggplant, cost per unit of output is lower. Altogether we find that Bt eggplant adoption increases profits by 25%–63%. Furthermore, adoption of Bt eggplant and the reduction of pesticide applications associated with it are likely to lead to improved health status and better environmental quality.

Our survey also collected information about the potential challenges associated with Bt eggplant. We find that farmers are not aware of the details of the new variety and the benefits and costs associated with it. Respondents are not well-trained on how to farm the new variety or the potential benefit associated with the Bt variety. In some cases, they spend more money on inputs that are not necessarily required, such as plot preparation, fertilizer use, irrigation, etc. Learning by doing associated with continuous use of the technology, as well as extension efforts can change farmer perceptions and improve their practice and enhance the benefits from adoption of Bt eggplants.

Table 3. Total Cost Information (in Bangladeshi Taka. [1USD=approx. 82 Taka])

	Bt	Non-Bt
Total cost (TC)	235,100	211,716
Chemical Pesticide Costs	34,478	51,370
	15% of TC	24% of TC
	33% reduction in TC	
Spray/week	3.11	4.58
	32% lower	

Conclusion

Introduction of Bt eggplant to Bangladesh is significant because it is one of the first GE vegetables introduced to the Indian subcontinent and one of the first GE-modified crops intended for direct human consumption. We surveyed 481 farmers in eight districts in Bangladesh, and found that adoption of Bt eggplant increased yield and raised profits. While there is no difference in cost per acre of farming eggplant between Bt and non-Bt varieties, costs per unit of eggplant is lower with Bt because of its higher yields.

Adoption of Bt eggplant also reduces pesticides sprays substantially compared to non-Bt varieties and thus improves farms safety. These results are consistent with the outcomes of studies of adoption of Bt cotton and Bt corn. Furthermore, farmers received a higher price for Bt eggplant, which shows that if GE products have desirable attributes to consumers, they will be able to fetch higher prices. We also find that the farmers didn't receive much guidance and information that could improve performance with the technology. Thus, if information about Bt eggplant is disseminated and farmers are well-trained, it might increase profitability even further and improve food security, farmer health, and environmental quality in Bangladesh.

This paper illustrates the large economic and health gains from adoption of GE technology in vegetable crops. Adoption of GE crops in vegetables may increase supply through higher yield and reduce cost per unit of output, and thus reduce price—improving food security. It will also likely improve worker safety in agriculture, by reducing exposure to pesticides. These impacts are especially significant in developing countries, so efforts should be made to reduce excessive barriers to adoption of GE varieties in crops consumed directly by humans. Finally, as the case of Bangladesh indicates, consumers will be willing to pay even more for Bt varieties if they have apparent advantages.

Authors' Bios

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