DRAFT REPORT

IMPACTS OF BT BRINJAL (EGGPLANT) TECHNOLOGY IN BANGLADESH

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With assistance from
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In collaboration with

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Prepared for

United States Agency for International Development

Grant Number: EEM-G-00-04-00013-00

Submitted by

International Food Policy Research Institute

Bangladesh Policy Research and Strategy Support Program

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February 2019

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TABLE OF CONTENTS

LIST OF Tables iii

LIST OF Figures v

Acronyms vi

Acknowledgments vii

Executive Summary 8

1. Introduction 1

1.1 Background and Motivation 1

1.2 Development of the Study 2

1.3 Objectives of the Study 2

1.4 Organization of the Evaluation Report 3

2. Research Design 4

2.1 Designing an Impact Evaluation: An Overview 4

2.2 Evaluation Methods 5

2.3 Method Used for Estimating Impacts of the Bt Brinjal Technology 6

2.4 Research Questions 7

2.5 Selection of Study Area 9

2.6 Sample Size Calculations 10

2.6.1 Overview 10

2.6.2 Sample Size Calculations for the Bt Brinjal Impact Evaluation 11

3. Data for the Evaluation 14

3.1 Baseline and Endline Surveys 14

3.1.1 Survey Questionnaires 14

3.1.2 Training 15

3.1.3 Survey Administration 16

3.1.4 Quality Control 17

3.2 Randomization and Balance 17

3.3 Attrition 19

3.4 Qualitative Research 20

3.4.1 Qualitative Protocol 21

3.4.2 Qualitative Fieldwork 22
4. Bt Brinjal Study Implementation 24
4.1 Project Partners 24
4.1.1 Bangladesh Agricultural Research Institute (BARI) 24
4.1.2 Department of Agricultural Extension (DAE) 24
4.1.3 International Food Policy Research Institute (IFPRI) 25
4.1.4 Agricultural Policy Support Unit (APSU) 26
4.1.5 Cornell University 26
4.1.6 Data Analysis and Technical Assistance (DATA) 26
4.2 Project Monitoring 26
4.2.1 Monitoring Training for DAE Officials 26
4.2.2 Farmers' Training 27
4.2.3 Input Packages for Farmers 27
4.2.4 Seedling Production and Transplantation 28
4.2.5 Pest Infestation 29
4.2.6 Flowering of Plants 29
5. Profile of Survey Households 30
5.1 Introduction 30
5.2 Characteristics of Survey Households 30
5.3 Summary 36
6. Impacts of Bt Brinjal: Pest Infestation and Insecticide Use 37
6.1 Introduction 37
6.2 Pests and Insecticides 37
6.3 Impact Analysis 41
6.4 Impact on the Toxicity Level of Pesticides Used 42
6.5 Summary 49
7. Impacts of Bt Brinjal: Brinjal Production and Yields 50
7.1 Introduction 50
7.2 Data and Descriptive Statistics 50
7.3 Basic Impact Results 52
7.4 Mechanisms and Extensions 54

7.5 Summary 54
8. Impacts of Bt Brinjal: Marketing, Costs and revenues 56
8.1 Introduction 56
8.2 Marketing of Brinjal 56
8.2.1 Type of Buyer 56
8.2.2 Location of Sale 58
8.3 Cost of Production 58
8.4 Impact Results 59
8.5 Summary 64
9. Impacts of Bt Brinjal: Health 65
9.1 Introduction 65
9.2 Data and Descriptive Statistics 65
9.3 Results 66
9.4 Pesticide handling 72
9.5 Summary 72
10. Conclusions 74
References 75

LIST OF TABLES

Table 2.1 List of study districts and upazilas 10
Table 2.2 Minimum sample size required for detecting changes in selected outcome indicators 12
Table 3.1 Selected study villages 16
Table 3.2 Mean values of baseline characteristics and primary outcomes, by treatment group 18
Table 3.3 Omnibus test of joint orthogonality where outcome is treatment status 18
Table 3.4 Reason for household being lost to follow-up, by treatment status 19
Table 3.5 Probit showing associations with loss to follow-up 20
Table 3.6 Qualitative data collection sample and activities 23
Table 4.1 Individual input package and cost 28
Table 5.1 Characteristics of Survey Household 31

Table 5.2 Electricity and structure of dwelling 32
Table 5.3 Types of latrines 32
Table 5.4 Household asset ownership 34
Table 5.5 Land tenure arrangements 35
Table 5.6 Share of crops on total cropped land at baseline 36
Table 6.1 Percentage of plots infested by pests 37
Table 6.2 Percentage of plants affected by pests in pest-infested plots, conditional on any damage being observed 38
Table 6.3 Number of times pesticides were applied 39
Table 6.4 Quantity of pesticides used 40
Table 6.5 Cost of pesticides used 40
Table 6.6 Impact of Bt brinjal cultivation on use of pesticides 41
Table 6.7 Globally Harmonized System of Classification and Labelling of Chemical (GHS) 42
Table 6.8 Features of popular pesticides used against common brinjal pests 43
Table 6.9 Popular pesticides used for common pests 45
Table 6.10 Disaggregation of pesticide toxicity 47
Table 6.11 Pesticide use toxicity score (PUTS) summary statistics 48
Table 6.12 Impact of Bt brinjal cultivation PUTS 48
Table 7.1 Mean levels of endline brinjal production and yield, by treatment status 51
Table 7.2 Impact of Bt brinjal on yields 53
Table 7.3 Impact of Bt brinjal on harvest, plot area, quantity discarded, paid out, retained for consumption and sold 55
Table 8.1 Marketing of brinjal at endline 57
Table 8.2 Input costs per hectare for Bt Brinjal and ISD-006 cultivation at endline 58
Table 8.3 Impact of Bt brinjal on cost 60
Table 8.4 Impact of Bt brinjal on cost of pesticide use 61
Table 8.5 Impact of Bt brinjal on revenue 62
Table 8.6 Impact of Bt brinjal on price for those who sold 63
Table 8.7 Impact of Bt brinjal on profit 63
Table 9.1 Descriptive statistics for analysis of self-reported health status, baseline 66
Table 9.2 Impact of Bt brinjal cultivation on self-report of symptoms consistent with pesticide poisoning 67

Table 9.3 Impact of Bt brinjal cultivation on consequences of symptoms consistent with pesticide poisoning 68
Table 9.4 Selected impacts on self-reported health outcomes, by sex 69
Table 9.5 Selected impacts on self-reported health outcomes, by chronic disease status 70
Table 9.6 Pesticide handling practices by treatment group and survey round 71

LIST OF FIGURES

Figure 2.1 Measuring impact based on outcomes from beneficiary and comparison groups....... 5
Figure 7.1 Kernel density functions for net yields per ha, by treatment status 52

ACRONYMS

ANCOVA	Analysis of Covariance
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BIHS	Bangladesh Integrated Household Survey
CAPI	Computer-assisted personal interviews
CGIAR	Consultative Group on International Agricultural Research
DAE	Department of Agricultural Extension
DATA	Data Analysis and Technical Assistance
DID	Difference-in-differences
FGD	Focus Group Discussion
FSB	Fruit and shoot borer
FTF	Feed the Future
GHS	Globally Harmonized System
GM	Genetically modified
GOB	Government of Bangladesh
IFPRI	International Food Policy Research Institute
KII	Key Informant Interview
MOA	Ministry of Agriculture
MoP	Muriate of Potash
NARS	National Agricultural Research System
PIM	CGIAR Research Program on Policies, Institutions, and Markets
PRSSP	Policy Research and Strategy Support Program
PUTS	Pesticide Use Toxicity Score
RCT	Randomized control trial
RIDIE	Registry for International Development Impact Evaluations
SAAO	Sub-assistant agriculture officer
Tk	Taka
TOT	Training of trainers
TSP	Triple Super Phosphate
UAO	Upazila agriculture officer
USAID	U.S. Agency for International Development

ACKNOWLEDGMENTS

This report is an output of the “Assessing the Impacts of Bt Brinjal Technology in Rural Bangladesh” evaluation. We thank the Ministry of Agriculture, Government of the People’s Republic of Bangladesh for its guidance on all aspects of this project and for partially funding this important study. We also appreciate the Bangladesh Agricultural Research Institute (BARI) and the Department of Agricultural Extension (DAE) for their excellent cooperation in implementing the study. We are particularly grateful to A.S.M. Mahbubur Rahman of BARI and Kazi Md. Shaiful Islam of DAE for their invaluable help throughout the study. We also thank Masuma Younus of the Agricultural Policy Support Unit (APSU) of the Ministry of Agriculture.

We gratefully acknowledge the United States Agency for International Development (USAID) for funding this study through the Policy Research and Strategy Support Program (PRSSP) in Bangladesh under USAID Grant Number EEM-G-00-04-00013-00; and the CGIAR Research Program on Policies, Institutions, and Markets (PIM). We acknowledge Lesley Perlman at the USAID Bureau for Food Security (BFS) for her valuable support throughout the study, from her guidance on the proposal to her constructive feedback on the survey questionnaires to ensuring that the study implementation was on track. We also thank Shahidur Bhuiyan at the USAID Bangladesh Mission for his support. Furthermore, we recognize Anthony M. Shelton at Cornell University for his technical advice during the study design.

Data for this report came from the 2017 Bt brinjal baseline survey and 2018 endline survey, both of which were approved by the Ministry of Agriculture. We are grateful to the Ministry of Agriculture for approving both survey rounds.

At IFPRI, we thank the Director of the Poverty, Health, and Nutrition Division Marie Ruel for her overall guidance; Md. Aminul Islam Khandaker for his support in coordinating and supervising the baseline and endline surveys; S.M. Tahsin Rahaman, Md. Redoy, and Waziha Rahman for conducting the qualitative field research; Aklima Parvin for supervising the qualitative research; Julie Ghostlaw for overall copy editing in addition to written contributions for this report; and Samita Kaiser for her help with the production of this report.

This study was made possible by the dedication and hard work of the survey enumerators and other staff from Data Analysis and Technical Assistance (DATA), a Bangladeshi consulting firm that carried out the 2017 Bt brinjal baseline survey and 2018 endline survey under IFPRI supervision. We specially thank Zahidul Hassan, Mohammad Zobair, and Imrul Hassan.

EXECUTIVE SUMMARY

[To be completed]

1. INTRODUCTION

1.1 Background and Motivation

Bangladesh is the first South Asian country to approve commercial cultivation of a genetically modified (GM) food crop: brinjal (eggplant) spliced with a gene from soil bacterium Bacillus thuringiensis. On October 28, 2013, Bangladesh's National Committee on Biosafety approved cultivation of four indigenous varieties of Bt brinjal, which is resistant to attacks by a common pest in South and Southeast Asia called the fruit and shoot borer. According to scientists of the Bangladesh Agricultural Research Institute (BARI), the protein in Bt brinjal disrupts the digestive systems of certain pests, causing them to die within three days of ingestion. The National Committee on Biosafety approved Bt brinjal for use, stating that the GM crop would significantly reduce the need to use pesticides. The Committee also announced that various safeguards would be put into place. In 2014, 108 farmers in 17 districts received seedlings of four varieties of Bt brinjal from the Ministry of Agriculture.

Agricultural technologies, such as the Bt brinjal technology, offer new opportunities that must be evaluated in an increasingly complex world where both supply and demand issues matter. There are significant factors that influence the effect of agricultural technologies on production as well as consumption. These include the characteristics of the existing agricultural systems, the agro-ecological conditions, socioeconomic status, sources of information about these technologies as well as beliefs, norms and cultural practices. From the existing agricultural systems, parameters that need to be considered include improved inputs, yields and productivity. Important agroecological variables include land and water resources, soil quality, and pest levels. Widespread adoption of productivity enhancing technologies has led to shifts in production with both positive and negative economic and environmental effects. On the other hand, agricultural technology has proven to be effective in the delivery of enhanced food availability and food quality and respond to environmental risks and uncertainties.

Upon request of the Ministry of Agriculture, the International Food Policy Research Institute (IFPRI) evaluated the impact of the Bt brinjal technology on production systems, producer welfare, and health outcomes. In collaboration with BARI and the Department of Agricultural Extension (DAE), IFPRI conducted the Bt brinjal impact evaluation in selected districts of north-western Bangladesh. IFPRI has outstanding capacity to conduct rigorous and state-of-the-art impact evaluations, and carried out numerous impact evaluations in Bangladesh and several countries in Asia, Africa, and Latin America.

IFPRI conducted the study under the ongoing Bangladesh Policy Research and Strategy Support Program (PRSSP) for Food Security and Agricultural Development, funded by the United States

Agency for International Development (USAID) and implemented by IFPRI. PRSSP conducts applied research to fill knowledge gaps on critical food security and agricultural development issues in Bangladesh; and thereby, facilitates evidence-based policy formulation and policy reforms to achieve the goal of sustainably reducing poverty and hunger.

1.2 Development of the Study

Upon request from the USAID's Bureau for Food Security (BFS), IFPRI-PRSSP developed a concept note for a Bt brinjal impact evaluation study in the USAID-supported Feed the Future (FTF) zone in south-western Bangladesh, and submitted the concept note to USAID in January 2015. USAID decided to fund the evaluation research. Since the Bangladesh Agricultural Research Institute (BARI) of the Ministry of Agriculture is responsible for Bt brinjal research, IFPRI and BARI agreed to conduct the Bt brinjal study jointly. In April 2015, IFPRI gave a presentation at BARI and explained the Bt brinjal impact evaluation design to scientists involved in Bt brinjal research and promotion. The Ministry of Agriculture agreed to provide funds to produce Bt brinjal seeds by BARI and to cover the costs of other inputs and training to farmers.

In a scoping visit to the FTF zone, the IFPRI team found that summer is the major brinjal-producing season in the region starting in March. However, BARI scientists were concerned about growing Bt brinjal during the summer season since all Bt brinjal trials were made for the winter season starting in November. Furthermore, the variety chosen for the study, BARI Bt Begun 4 (ISD-006), is not grown in the south-western region. Therefore, BARI advised IFPRI to change the study location from the south-western region to the north-western region.

In April 2017, the IFPRI team went on a second scoping visit in the north-western region to assess the feasibility of conducting the study during the winter season. The IFPRI team found that farmers in the region grow brinjal during summer and winter. Based on this finding, IFPRI and its partners decided to conduct the study in four north-western districts during the winter season starting in November 2017.

1.3 Objectives of the Study

The Bt brinjal impact evaluation is designed to provide a thorough understanding of the impact of uptake and adoption of the Bt brinjal technology among Bangladeshi farmers, mimicking as much as possible the real-world context of a roll-out. To this end, this study aimed to provide important insights of the efficacy of this new technology, based on which the Ministry of Agriculture may guide its future implementation strategy. The results of the study will also be useful for various other stakeholders such as scientists at the National Agricultural Research System (NARS), government policy makers, USAID, the media, and the civil society in Bangladesh. The study has the following specific objectives:

1. Estimate, using a rigorous impact evaluation, the impact of growing Bt brinjal by farmers on key outcomes:
    a. Use of pesticide for brinjal cultivation
    b. Brinjal yields
    c. Cost of production
    d. Net crop income
    e. Human health outcomes
2. Document and disseminate results and lessons learned from the study.

1.4 Organization of the Evaluation Report

This report presents the results of the Bt brinjal evaluation. It is organized in 10 sections. Section 2 presents the research design. Section 3 describes the data used for the evaluation. Section 4 describes the project implementation process. Section 5 gives a profile of survey households. Section 6 presents the impact of Bt brinjal on pesticide use. Section 7 shows impact on brinjal production and yields. Section 8 provides impacts on marketing, costs, and revenue. Section 9 shows the impacts on health. Section 10 summarizes the main findings and provides conclusions.

2. RESEARCH DESIGN

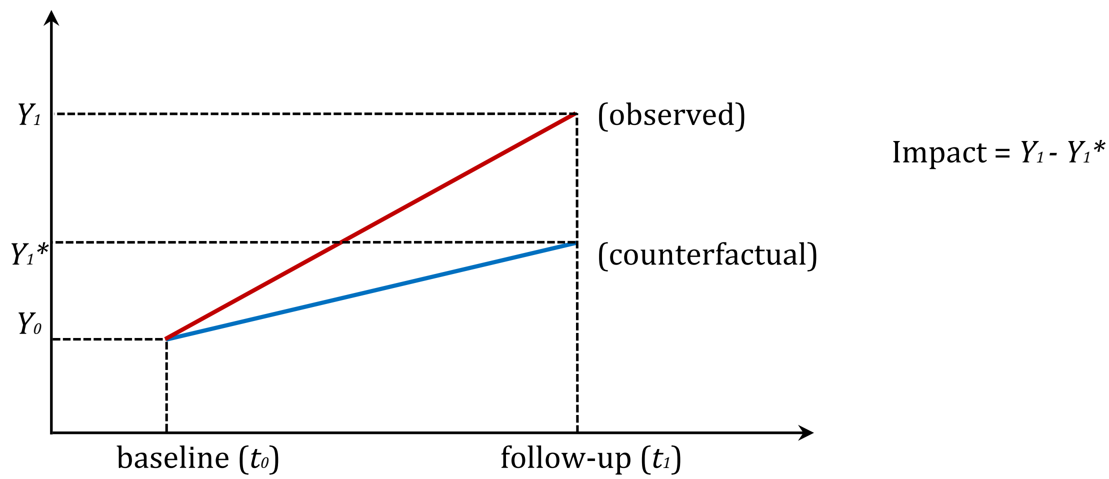
2.1 Designing an Impact Evaluation: An Overview

In order to design an effective impact evaluation, it is necessary to understand how the evaluation demonstrates impact. The purpose of an impact evaluation is to compare outcomes for beneficiaries in a particular program (observed outcomes) with the beneficiaries' outcomes had they not participated in the program (counterfactual outcomes). The difference between the observed outcomes for beneficiaries and the counterfactual outcomes represent the causal impact of the program. The fundamental challenge of an impact evaluation is that it is not possible to observe the exact same beneficiaries both participating in the program and not participating in the program at the exact same time; therefore, the counterfactual outcomes for beneficiaries are unknown. All evaluation strategies are designed to find a method for constructing a proxy for these counterfactual outcomes.

Most evaluations measure counterfactual outcomes for beneficiaries by constructing a comparison group of similar households from among non-beneficiaries. Collecting data on this comparison group makes it possible to observe changes in outcomes for people not participating in the program and to control for some other factors that affect outcomes, which reduces bias in the impact estimates.

Figure 2.1 shows how information on a comparison group can be used to measure program impact by removing the counterfactual from the observed outcome for beneficiaries. In the figure, the outcome variable is represented on the *Y* axis, and time is represented on the *X* axis. A household survey is conducted to measure the outcome in two periods: the baseline at t_0 and the follow-up at t_1. In the figure, at baseline the average outcome for both the households benefiting from the program and those in the comparison group is at the level of Y_0. After the program is completed, the follow-up survey (t_1), demonstrates that the group participating in the program has an outcome level of Y_1 while the comparison group has an outcome level of Y^*_1. The impact of the program is measured as $Y_1 - Y^*_1$. If a comparison group had not been included, the impact might have been misrepresented (and overstated) as the observed change in the outcome for the beneficiary group: $Y_1 - Y_0$.

Figure 2.1 Measuring impact based on outcomes from beneficiary and comparison groups



In constructing a comparison group for the evaluation, it is important to ensure that the group is as similar as possible to the program group before the start of the program. To understand why, consider estimating the impact of introducing a new agricultural technology among smallholder farmers on rice yields as the difference in average rice yields between beneficiaries and a random sample of non-beneficiary farmers. The problem with this approach is that non-beneficiaries are different from program beneficiaries in ways that make them an ineffective comparison group. If the evaluation does not control for these differences prior to initiating the program, impact estimates will be biased. The most common sources of bias are targeting or program placement bias and bias due to self-selection by beneficiaries concerning the decision to participate.

2.2 Evaluation Methods

We used a randomized controlled trial (RCT) to quantitatively measure the impact of the introduction of Bt brinjal. We complemented this using qualitative research methods.

RCTs are widely considered to be the most rigorous approach to constructing a comparison group for an evaluation. The method involves designing a field experiment by random assignment of the program among comparably eligible communities or households. Those that are randomly selected out of the program form a control group, while those selected for the program are the treatment group. When RCT is properly implemented, differences in outcomes between the treatment and control groups should be free of bias and can reliably be interpreted as causal impacts of the program. The intuition is that, because assignment of the program is randomly determined and not correlated with the outcome variables, differences in outcomes over time between randomly selected treatment and control groups must be a result of the program.

RCT estimates are further strengthened by measuring outcome variables for treatment and comparison groups before and after the program begins. This makes it possible to construct "difference-in-differences" (DID) estimates of program impact, defined as the average change in the outcome in the treatment group, T, minus the average change in the outcome in the comparison group, C. Mathematically, this is expressed as

$$\Delta_{DID}^{ATT} = \left(y_1^T - y_0^T\right) - \left(y_1^C - y_0^C\right).$$

The main strength of DID estimates of program impact is that they remove the effect of any unobserved variables that represent persistent (time-invariant) differences between the treatment and comparison group. This helps to control for the fixed component of various contextual differences between treatment and comparison groups, including depth of markets, agro-climatic conditions, and any persistent differences in infrastructure development. As a result, DID estimates can lead to a substantial reduction in selection bias of estimated program impacts.

2.3 Method Used for Estimating Impacts of the Bt Brinjal Technology

IFPRI's impact estimation strategy for the Bt brinjal technology adoption study relied on the clustered RCT design of the evaluation. Random assignment of clusters (villages) assured that, on average, farm households will have similar baseline characteristics across treatment and control groups. Such a design eliminates systematic differences between treatment and control households and minimizes the risk of bias in the impact estimates due to "selection effects" (Hidrobo et al. 2014).

We used Analysis of Covariance (ANCOVA) regression to estimate impacts of the Bt brinjal technology using the longitudinal data on treatment and control households. The ANCOVA specification allows a household's outcome at follow-up to depend on the same household's outcome at baseline as well as on the household's treatment status and an error term (accounting for any omitted observable or unobservable factors). In case of high variability and low autocorrelation of the data at baseline and follow-up, ANCOVA estimates are preferred over difference-in-difference estimates (McKenzie 2012). Intuitively, if autocorrelation is low, then difference-in-difference estimates will over-correct for baseline imbalances. ANCOVA estimates, on the other hand, will adjust for baseline imbalances according to the degree of correlation between baseline and follow-up, as the specification allows estimating autocorrelation rather than imposing it to be unity. The ANCOVA model that we estimated is the following:

$$Y_h = \propto + \beta T_h + \gamma Y_{h,base} + \varepsilon_h \,,$$

where Y_h is the outcome of interest (e.g., Bt brinjal yields) for farm household h at follow-up and $Y_{h,base}$ is the outcome of interest at baseline. T is an indicator for whether household h is in the treatment group (treatment = 1, control = 0), and β is the ANCOVA impact estimator. In other words, β represents the amount of change in outcome, Y, which is due to household h being assigned to the treatment group. To test whether the ANCOVA impact estimator is statistically different for the treatment group, we will conduct Wald tests of equality and report the p-values.

The randomization of treatment status, the selection of farmers based on their willingness to grow Bt brinjal and the use of the ANCOVA estimator collectively provide us the means of ensuring that changes in outcome variables can be ascribed to the adoption of Bt brinjal.

Throughout the report, for outcomes where two rounds of data can be used, we estimated both the "base" ANCOVA specification above, with standard errors adjusted for clustering at the village level, and what we refer to as an "extended" ANCOVA specification. The extended specification includes additional baseline covariates, in order to improve precision as well as to further address any baseline imbalances between arms. We chose a parsimonious list of baseline covariates for the extended specification, roughly following two criteria (Bruhn and McKenzie 2009): (1) we believe the covariates "matter" for our outcomes of interest, meaning they are likely to be significantly associated with key outcomes; (2) differences in the baseline covariates between intervention arms appear "large." We also chose baseline covariates with non-missing values in our data, so that including them does not cause us to drop household observations from our estimation. The final list of baseline covariates included in the extended specifications is as follows: Age years of education of household head, number of years worked as a farmer of person with primary responsibility for brinjal production; wealth index; and land operated (acres) at baseline.

We assessed the robustness of our findings by comparing results from the basic model, the extended model, winsorizing (this deals with outliers in the outcome variable by setting the values of the bottom two percentiles equal to the second percentile and by setting the values of the top two percentiles equal to the 98^{th} percentile), and by taking log of the dependent variable.

2.4 Research Questions

We used quantitative and qualitative data to address the following research questions:

Production

1. Does the cultivation of Bt brinjal change the quantity of pesticides applied to brinjal? (Yes/No). How large is this change?

2. Does the cultivation of Bt brinjal change the frequency with which pesticides are applied to brinjal? (Yes/No). How large is this change?
3. Does the cultivation of Bt brinjal change the cost of applying pesticides to brinjal? (Yes/No). How large is this change?
4. Does the cultivation of Bt brinjal change the prevalence of secondary insect infestations? (Yes/No). How large is this change?
5. Does the cultivation of Bt brinjal change the amount of labor used to produce brinjal? (Yes/No). How large is this change? If this change occurs, does it reflect a change in the use of hired labor (Yes/No; how large is the change) or family labor (Yes/No; how large is the change)? If family labor changes, who in the family changes their labor supply and by how much?
6. Does the cultivation of Bt brinjal change other production practices? (Yes/No). If so, what are those changes?
7. Does the cultivation of Bt brinjal change other (i.e., not pesticides or labor) costs associated with brinjal production? (Yes/No). What costs change? How large is this change?
8. Does the cultivation of Bt brinjal change the amount of brinjal produced? (Yes/No). How large is this change?
9. Does the cultivation of Bt brinjal change brinjal yields (i.e., production / area cultivated)? (Yes/No). How large is this change?
10. Why do these changes occur? Are they observed uniformly across the sample or are they associated with specific farmer or locational characteristics?

Marketing

11. Compared to conventional varieties, is Bt brinjal easier or more difficult to sell in local markets? Why?
12. Has the introduction of Bt brinjal brought in new traders into local markets for brinjal? If so, who are these individuals? Have other traders left these markets?
13. Is Bt brinjal sold at a different price compared to conventional brinjal? (Yes/No). Is this a higher or lower price? How large is the price differential? Is this a constant price differential or does it vary? If it varies, by how much and why?
14. How do farmers' experiences in marketing Bt brinjal compare to marketing conventional brinjal? What factors affect these experiences?

Income

15. Does the cultivation of Bt brinjal cause gross revenues from brinjal production (total production *x* price received) to change? How large is this change?
16. Does the cultivation of Bt brinjal cause net revenues from brinjal production (gross revenues minus all costs) to change? How large is this change?

17. If changes in gross or net revenues occurs, what accounts for these? Changes in revenues, in costs or some combination of these?

Health

18. Does the cultivation of Bt brinjal reduce household self-reports of symptoms consistent with pesticide poisoning? (Yes/No). How large is this change? Who in the household (by age/sex/relationship to household head) is affected by this change?
19. Does the cultivation of Bt brinjal reduce the number of days that household members are too ill to work? (Yes/No). How large is this change? Who in the household (by age/sex/relationship to household head) is affected by this change?
20. Does the cultivation of Bt brinjal change healthcare and expenditures related to health care? (Yes/No). How large is this change? Who in the household (by age/sex/relationship to household head) is affected by this change?

2.5 Selection of Study Area

The Bt brinjal varieties released by BARI are best suited to winter cultivation with sowing of seeds beginning in September/October and transplanting seedlings in November. For this reason, we concentrated on localities where farmers predominantly cultivate brinjal in the winter (Rabi) season. Further, given our interest in assessing Bt brinjal as a cash crop (rather than one simply for home consumption), these localities also need be characterized by good physical infrastructure and well-functioning markets for brinjal. In consultation with officials from BARI and the Department of Agricultural Extension (DAE), we purposively selected four districts in the northwestern region that satisfy these criteria: Bogra, Gaibandha, Naogaon, and Rangpur.

Within the selected districts, DAE officials provided us, by upazilas (sub-districts), lists of villages where brinjal is cultivated predominantly in the winter season and the number of brinjal farmers in each village. Using these lists, we purposively selected 10 upazilas with a high concentration of villages with substantial number of brinjal farmers. Table 2.1 provides the list of the selected upazilas for the Bt brinjal study.

Table 2.1 List of study districts and upazilas

District	Upazila
Bogra	Shahzahanpur
Gaibandha	Gaibandha Sadar
	Palashbari
	Gobindoganj
Naogaon	Dhamoirhat
	Mande
Rangpur	Pirgacha
	Pirganj
	Mithapukur
	Gongachara

Source: Constructed by authors.

2.6 Sample Size Calculations

2.6.1 Overview

It is important to ensure that the sample size is sufficiently large for treatment impacts to be feasibly detected in the outcomes of interest. While increasing sample size requires devoting additional resources, having too small a sample is a danger that can undermine the purpose of undertaking the evaluation. If the sample is too small, even a substantial treatment impact in a key outcome may be indistinguishable from inherent variability in the outcome.

The role of sample size calculations is to formally analyze what study designs will allow sufficient power to detect a specified minimum change in a given outcome. These calculations can also be used to consider implications of known limitations in study design. For example, if there are specific constraints on sample size (for example, for practical/logistical reasons), the minimum detectable effect in each outcome can be calculated, given the constraints. If the minimum detectable effect in a particular outcome is unreasonably large to expect as a treatment impact, this insight can then guide the choice of outcomes considered to be the focus of the study, which can in turn guide the research questions that are posed and shape the design of the survey questionnaire. To summarize–and to be clear on this point–sample size calculations do not indicate what the sample size must be. Rather, they indicate what magnitude of effects we can reasonably expect to observe, given the design of the intervention.

2.6.2 Sample Size Calculations for the Bt Brinjal Impact Evaluation

The sample size needed for the Bt brinjal impact evaluation depends on several factors: (1) the outcomes that are of the greatest interest to researchers and program managers; (2) the minimum size of change in those outcomes that researchers would like to observe; (3) the degree of variability in those outcomes; (4) the extent to which there is correlation in outcomes within localities; (5) the desired level of statistical power; and (6) the level of desired statistical significance. Sample sizes increase with reductions in the size of change that the evaluation is attempting to uncover; greater variability in outcomes; increased correlation of outcomes; and higher statistical power.

In the context of the Bt brinjal impact evaluation, our calculations also take into account that treatment is randomized at the village (cluster) level. In sample size calculations for cluster-randomized studies, not only the number of households and the number of clusters matter, but also the inherent similarity of households within a cluster. The measure that captures this similarity for each outcome is referred to as its "intra-cluster correlation" – that is, in the absence of any treatment, a measure of the extent to which the outcome varies across households within a cluster relative to how much it varies across clusters.

The value of the intra-cluster correlation for any outcome is likely to depend on the context of the data. Since it is necessary to conduct sample size calculations prior to collecting the data, the accepted approach to estimating intra-cluster correlations for sample size calculations is to use values calculated from existing comparable datasets.

For the Bt brinjal impact evaluation, we used parameters derived from a nationally representative IFPRI survey, the Bangladesh Integrated Household Survey (BIHS), conducted in 2011-2012.[1] We used brinjal yields per hectare and total cost of pesticide use per hectare as the outcome indicators. BARI officials informed us cost of pesticides is a major cost of brinjal production. They also reported that the fruit and shoot borer insect causes considerable loss in brinjal production, resulting in a significant reduction in brinjal yields.

We followed the standard practice of calculating the sample size that, given the expected change in the selected outcome indicators, would provide an 80 percent chance (the power of the test) of correctly rejecting the null hypothesis that no change occurred, with a 0.05 level of significance.

The estimated necessary minimum sample size is reported in Table 2.2. For example, to detect

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[1] Dataset: Ahmed, Akhter, 2013, “Bangladesh Integrated Household Survey (BIHS) 2011-2012”, http://hdl.handle.net/1902.1/21266 UNF:5:p7oXR2unpeVoD/8a48PcVA== International Food Policy Research Institute [Distributor] V3 [Version]

a minimum, statistically significant increase in brinjal yields per hectare of 30 percent between treatment and control groups, a minimum total sample size of 180 clusters (villages) and 1,046 farm households are required, with 523 farm households for the treatment group and 523 households for the control group. For reduction of pesticide cost per hectare as an outcome indicator, 187 clusters and 1,120 farm households (560 treatment and 560 control households) are required to detect a minimum of 40 percent reduction in pesticide costs. We need a sample size large enough to assess both impacts (that is, at least 1,120 farm households) and also allow for the possibility that some households may drop out between baseline and endline. Therefore, for the Bt brinjal impact evaluation, we used 200 clusters/villages (100 treatment and 100 control villages) and 1,200 farm households (600 treatment and 600 control households). Each cluster included six farm households.

Table 2.2 Minimum sample size required for detecting changes in selected outcome indicators

		Required Number of clusters	Required number of farm households		
Indicators	Minimum impact		Treatment	Control	Total
Brinjal yield per hectare	An increase of 25%	281	701	701	1,402
Brinjal yield per hectare	An increase of 30%	180	523	523	1,046
Pesticide cost per hectare	A reduction of 35%	250	731	731	1,462
Pesticide cost per hectare	A reduction of 40%	187	560	560	1,120

Source: Calculated using data from the IFPRI Bangladesh Integrated Household Survey, 2011-2012.

2.6.3 Selecting Treatment and Control Groups

The sampling process for the treatment and the control groups will include the following steps:

- The Bt brinjal varieties currently released by BARI are best suited to winter cultivation. For this reason, we need to work in localities where farmers predominantly cultivate brinjal in the winter (Rabi) season, with planting of seeds beginning in September/October (Ashwin/Kartik month of the Bangla calendar). Further, given our interest in understanding the marketing and sale of Bt brinjal, these localities must also be characterized by good physical infrastructure and well-functioning markets for brinjal. In consultation with officials from BARI and DAE, we have identified four districts that satisfy these criteria: Bogra, Gaibandha, Naogaon, and Rangpur, balancing the value of surveying a diverse set of localities with the practicalities of ensuring timely delivery of Bt brinjal seeds prior to the start of the planting season.

- DAE officials in the four selected districts provided a list of villages where brinjal is cultivated predominantly in the winter season and the number of brinjal farmers in each village by upazila to IFPRI. Using these lists, we purposively selected upazilas with a high concentration of villages, defined as having at least 15 brinjal farmers per village.
- We compiled a list of villages within these upazilas where there are at least 15 brinjal farmers.
- From this list, we randomly assigned 100 villages to the treatment group and 100 villages to the control group (200 villages selected).
- We conducted a 100 percent census of the 100 selected treatment villages and the 100 selected control villages, and listed all brinjal-growing farmers from the village census lists.
- From the census list of brinjal farmers of the selected treatment and control villages, we identified farmers willing to grow Bt brinjal and the non-Bt brinjal (ISD-006) on 10-decimal plots during the planting season beginning in November 2017. This selection criteria ensured that farmers selected for the study have similar attributes in terms of risk-taking behavior and preferences. We randomly selected six farmers from each of the treatment and control villages and confirmed their participation in the study (1,200 total farmers selected).

3. DATA FOR THE EVALUATION

The information collection approach used to evaluate the Bt brinjal study involved combining quantitative surveys and qualitative semi-structured key informant interviews and focus group discussions. This mixed method of data collection provided a rich pool of data and powerful analysis that would not have been available with any of these methods on their own. Gender disaggregated information was collected wherever it was meaningful.

The required quantitative data for the impact evaluation mostly came from two household surveys. A baseline survey was carried out from November 25-December 13, 2017. An endline survey was conducted from July 4-17, 2018 to assess the impacts of the interventions.

The surveys included farm households cultivating Bt brinjal and conventional brinjal. IFPRI has extensive experience in the design and implementation of similar surveys in Bangladesh and many other countries.

3.1 Baseline and Endline Surveys

3.1.1 Survey Questionnaires

The Bt brinjal survey questionnaires included modules that, together, provide an integrated data platform to answer the research questions. The modules of the questionnaires are listed below:

- Household demographic composition, education attainment, occupation and employment, dwelling characteristics, water and sanitation
- Illness (all household members) and health status during crop growing seasons
- Acquisition of productive and consumption assets
- Savings and loans
- Land and ponds owned and operated
- Brinjal production
- Seedling and seedbed production and planting for brinjal
- Area planted and irrigation for brinjal
- Usage of fertilizers and pesticides for brinjal
- Pesticide for brinjal (use and frequency of pesticide in the last 12 months)
- Pest infestation in brinjal plots
- Rental cost of tools, machinery and draft animal for brinjal
- Household labor usage by gender for brinjal plantation, production, harvesting and post-harvest stage
- Hired labor usage by gender for brinjal plantation, production, harvesting and post-harvest stage

- Monthly brinjal harvest and sale in last 12 months
- Marketing of brinjal
- Shocks affecting brinjal production
- Pesticide handling, protective measures while spraying pesticide for brinjal farming
- Production of crops other than brinjal
- Agricultural extension services
- Program participation, training and input received

3.1.2 Training

For implementing the baseline household survey, IFPRI contracted Data Analysis and Technical Assistance (DATA), a Bangladeshi consulting firm with expertise in conducting complex surveys and data analysis. DATA worked under the supervision and guidance of senior IFPRI researchers. DATA's capacity to conduct surveys that collect high quality data was largely built by IFPRI over the past two decades.[2]

In January 2017, IFPRI provided a village list and the draft census questionnaire to DATA. In August 2017, the villages were randomized, with 100 control and 100 treatment villages selected (Table 3.1). From July 29-August 8, 2017, DATA trained a 40-person survey team to conduct the census, which was then conducted from August 9-21, 2017. On August 31, 2017, farmers were selected to participate in the study.

IFPRI researchers prepared a draft baseline survey questionnaire. The draft questionnaire was peer-reviewed and revised to address comments and suggestions. In October 2017, IFPRI and DATA pre-tested the Bt brinjal baseline survey questionnaire in Belabo Upazila in Narshingdi District, a major vegetable growing area, and Trishal Upazila in Mymensingh District. Field testing identified issues with the questionnaires or additional rules that were needed to address difficult cases. The questionnaire was revised, DATA programmed the questionnaire for computer-assisted personal interview (CAPI) under IFPRI-PRSSP's supervision, and the survey questionnaire was finalized.

DATA provided experienced survey enumerators and supervisors to administer the survey, most of whom hold master's degrees in social science, nutrition, or home economics. From November 6-22, 2017, IFPRI researchers and DATA experts trained 45 experienced male enumerators and 10 male supervisors. The survey enumerators' training consisted of a formal classroom component, as well as closely monitored practice fieldwork. In the formal training,

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[2] DATA carried out all IFPRI surveys in Bangladesh, including more than 50 household surveys and several market, school, and other institutional surveys. In addition, DATA has conducted numerous surveys for various international organizations, such as the World Food Programme (WFP)-Bangladesh, the World Bank, the European Union, the U.S. Department of Agriculture, CARE-Bangladesh, World Vision-Bangladesh, the Population Council–New York, Save the Children (USA), Tufts University School of Nutrition Science and Policy, and the IRIS Center at the University of Maryland.

IFPRI researchers briefed the enumerators and supervisors on the objectives and methods of the survey, the sampling design, and the responsibilities of the enumerators. They were trained on how to carry out the interviews, including line-by-line explanation and interpretation of the questionnaires, the flow and skip-patterns, definitions, and explanations of how to handle unusual cases and when to contact the supervisor for assistance.

Table 3.1 Selected study villages

Division	District	Upazila	Unions	Treatment Village	Control Village
Rajshashi	Bogra	Shajahanpur	4	8	12
Rajshashi	Naogaon	Dhamoirhat	7	12	8
Rajshashi	Naogaon	Manda	8	12	8
Rangpur	Gaibandha	Gaibandha Sadar	8	9	11
Rangpur	Gaibandha	Gobindaganj	6	10	10
Rangpur	Gaibandha	Palashbari	9	8	12
Rangpur	Rangpur	Gangachara	7	10	10
Rangpur	Rangpur	Mithapukur	6	12	8
Rangpur	Rangpur	Pirgachha	7	10	10
Rangpur	Rangpur	Pirganj	12	9	11
Total			74	100	100

Source: Constructed by authors.

Field supervisors received additional training related to their supervisory and editing role. They were trained on the quality control process, cross checking, editing and coding of the questions, security and confidentiality issues, and the delivery of the completed questionnaires to the DATA office in Dhaka for simultaneous data entry.

3.1.3 Survey Administration

DATA carried out the baseline household survey from November 25-December 13, 2017 and the endline household survey from June 20-July 4, 2018, under the supervision and guidance of IFPRI researchers. Going into the field, the teams of enumerators were equipped with various documents (for example, survey manuals and tablets for CAPI), and GPS units for geo-referencing.[3] The APSU Research Director, Ministry of Agriculture, Government of Bangladesh issued letters of authorization to conduct the survey.

[3] GPS's were imported from the USA for the household survey.

The enumerators conducted the interviews one-by-one and face-to-face with the respondents assigned to him. The enumerators were supervised by the field supervisors. Each field supervisor was responsible for his defined region. All field staff reported their activities to their supervisors using a standard progress report form. Completed questionnaires were delivered electronically to the DATA central office on a regular basis for further quality control and validation during data entry.

3.1.4 Quality Control

IFPRI and DATA worked diligently to ensure the quality of both rounds of the household survey data. In the field, survey supervisors routinely oversaw interviews conducted by enumerators, and the use of CAPI reduced possibility of human error during data entry, using skip pattern and other programmed responses. If, however, inconsistencies in responses were detected, then the supervisors visited the relevant respondents to find out the reasons and corrected the responses as needed. In addition, the supervisors made random checks of about 10 percent of the completed questionnaires by revisiting the sample households. IFPRI researchers made frequent field visits to supervise the fieldwork.

3.2 Randomization and Balance

IFPRI's impact estimation strategy for the Bt brinjal technology adoption study relied on the clustered RCT design of the evaluation, using villages as clusters. The randomization method used for this study is described in Section 2.3, and the process of selecting treatment and control groups is described in Section 2.6.3. Note that we followed a straightforward randomization exercise; there were not multiple phases or stratification involved.

As specified in our pre-analysis plan submitted on the Registry for International Development Impact Evaluations (RIDIE),[4] we assess balance over the following characteristics: age of household head; education of household head; wealth status (based on a principal components analysis of ownership of consumer durables and housing quality); land operated during baseline, 2016-17 and number of years working as a farmer.[5] In addition we assessed balance over baseline values for our two primary outcomes: brinjal yields (production per ha) and pesticide costs (Taka per ha). Following McKenzie (2015), we focused on the magnitude of the differences between treatment and control households and an omnibus test of joint orthogonality. Results are shown in Tables 3.2 and 3.3.

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[4] IFPRI's pre-analysis plan for this study is available at the following link: http://ridie.3ieimpact.org/index.php?r=search/detailView&id=682

[5] As noted in our pre-analysis plan, because more than 95 percent of households are male headed, we do not assess balance on this characteristic.

Table 3.2 Mean values of baseline characteristics and primary outcomes, by treatment group

Baseline Controls	Treatment mean	Control mean	Difference	T statistic
Years of education of the brinjal grower	5.8	5.3	0.5	1.90*
Age of brinjal grower	46.1	46.2	-0.1	-0.20
Years of working as a farmer	26.9	26.6	0.3	0.41
Size of operated land (in acres)	1.6	1.4	0.2	2.09**
Wealth Index	0.020	-0.025	0.045	0.58
Brinjal yield in baseline (kg/ha)	27893	33746	-5853	3.99***
Cost of pesticides used in baseline (Tk/ha)	28605	31620	-3015	1.63

Source: Constructed by authors.
Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table 3.3 Omnibus test of joint orthogonality where outcome is treatment status

Baseline characteristic	Marginal effects	SE
Years of education of the brinjal grower	0.007	0.004
Age of brinjal grower	-0.001	0.002
Years of working as a farmer	0.002	0.002
Size of operated land (in acres)	0.020	0.017
Wealth Index	-0.003	0.010
Brinjal yield in baseline (kg/ha)	-2.11×10^{-6}**	1.04×10^{-6}
Cost of pesticides used in baseline (Tk/ha)	-2.45×10^{-7}	7.25×10^{-7}
Joint test of orthogonality		
Wald chi2 = 10.91		
p-value = 0.14		

Source: Constructed by authors.
Note: Standard errors clustered at the village level. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Sample size is 1166.

The one noteworthy difference between treatment and control households is that, at baseline, yields were higher in control households. However, a Wald test does not reject the null hypothesis that the regressors are jointly equal to zero, implying that imbalance between treatment and control households in baseline characteristics is not a concern for this study.

3.3 Attrition

Our baseline sample consists of 1,196 households (598 treatment households and 598 control households). We successfully traced and re-interviewed 1,176 households at endline, including 593 treatment households and 583 control households, losing only 20 households in total for an attrition rate of 1.7 percent. Table 3.4 gives the reasons why households were lost to follow-up.

Table 3.4 Reason for household being lost to follow-up, by treatment status

	Treatment	**Control**
	Number	
Migrated	0	2
Chose not to continue cultivating brinjal	2	7
Cultivated other brinjal variety	0	4
Not traced for other reasons	3	2

Source: 2017 Baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Next, we estimate a model where the outcome variable equals one if the household was lost to follow-up for any reason, zero otherwise. Our regressors include treatment status, the control variables we include in all mode specifications and our two primary outcomes, brinjal yield at baseline and cost of pesticides (Tk/ha). Standard errors account for clustering at the level of randomization, the village. Results, reported as marginal effects, are reported in Table 3.5.

Table 3.5 Probit showing associations with loss to follow-up

Baseline Controls	Marginal effects	SE
Treatment status is Bt brinjal	-0.016**	0.008
Years of education of the brinjal grower	0.001*	0.0006
Age of brinjal grower	0.0002	0.0004
Years of working as a farmer	-0.0003	0.0003
Size of operated land (in acres)	-0.002	0.004
Wealth Index	-0.001	0.001
Brinjal yield in baseline (kg/ha)	-2.07×10^{-7}	1.40×10^{-7}
Cost of pesticides used in baseline (Tk/ha)	5.68×10^{-8}	6.14×10^{-8}
Joint test of orthogonality		
Wald chi2 = 12.70		
p-value = 0.12		

Source: Constructed by authors.
Notes: Standard errors clustered at the village level. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Sample size is 1196.

A Wald test does not reject the null hypothesis that the regressors are jointly equal to zero. Households randomized into Bt brinjal cultivation were less likely to attrit, but while this coefficient is statistically significant, the magnitude is small (1.6 percentage points). Given the results shown in Table 3.5, and given the very low level of attrition, we do not implement the weighting methodology proposed by Fitzgerald et al. (1998a, b). Attrition is not a concern for this study.

3.4 Qualitative Research

IFPRI's three-member qualitative research team, coordinated by IFPRI's Senior Project Manager, conducted the qualitative component of the Bt Brinjal study. The IFPRI qualitative research team brings an accumulated 21 years of experience in qualitative field research in Bangladesh, with extensive training in qualitative data collection and analysis approaches (for example, coding, categorizing, clustering, and building relationships) and an in-depth understanding of the country context.

Initially, IFPRI planned to conduct two rounds of qualitative research in March and June 2018. However, due to incessant rain and consequent flooding, there were delays in transplanting seedlings from the seedbed to the main plot in some places by three to four weeks. As a result, we postponed the first round of qualitative fieldwork, which was originally planned for March to May 2018. Given that the second round was scheduled for June 2018, USAID and IFPRI agreed to combine the two rounds of fieldwork, which was conducted in July 2018. We maintained the content, participants, and format of the qualitative fieldwork, but instead of the original two rounds, we conducted one round of qualitative fieldwork in July 2018.

Overall, the qualitative field research aimed to validate and explore changes in the quantity, frequency and cost of applying pesticides; the prevalence of secondary insect infestations; the amount of labor used to produce brinjal, influence on production and yields to other brinjals and farmer's experience in marketing between Bt brinjal and conventional (that is, non-Bt) brinjal.

To this end, IFPRI conducted focus group discussions (FGDs) with Bt brinjal farmers, key informant interviews (KIIs) with concerned DAE officials, and KIIs with market traders operating in these villages to respond to the study's research questions.

3.4.1 Qualitative Protocol

The field research aimed to validate and explore changes in the quantity, frequency and cost of applying pesticides; the prevalence of secondary insect infestations; the amount of labor used to produce brinjal, influence on production and yields to other brinjals and farmer's experience in marketing between Bt brinjal and conventional (that is, non-Bt) brinjal.

IFPRI-PRSSP decided to remove Bogra District from the qualitative research for various reasons. First, since Bogra District only had one village, including this area may further delay completion of data collection and raise costs. Second, as Bogra District has similar agricultural marketing and production characteristics as Rangpur and Gaibandha districts, it was assumed that the study could glean representative insights from Rangpur and Gaibandha districts. Therefore, Gaibandha, Naogaon, and Rangpur districts were selected for this qualitative research.

The study included all nine upazilas from the three study districts to get maximum diversity in the sample for the qualitative fieldwork. From each of the nine upazilas, the study randomly selected one village from the treatment group with an aim to get diversity on locational characteristics, brinjal production-related issues, marketing, and application of pesticides.

in nine treatment villages (three villages per district x three districts), focusing on the 10 research questions about Bt brinjal production listed in Section 2.4. Particular attention was given to question #10, seeking to understand in farmers' own words why these changes have occurred and why they might vary with specific farmer or locational characteristics. In addition, we undertook key informant interviews (KIIs) with concerned DAE officials to get their perspectives on the cultivation of Bt brinjal, again with particular focus on research question #10.

These discussions will center on the four research questions about the marketing of Bt brinjal with particular attention to question #14, seeking to understand farmers' experiences marketing Bt brinjal. We will complement this with KIIs with market traders operating in these villages, understanding from their perspective the challenges and opportunities that Bt brinjal brings.

- **FGDs with farmers:** From each of the nine randomly selected villages, all six Bt brinjal farmers per village participated in FGDs. Therefore, in total, there were nine FGDs conducted with a total of 54 FGD participants (six farmers per village * nine villages). The FGDs sought to ascertain farmers' experiences on Bt brinjal production and marketing.

- **KIIs with agriculture extension agents**: A semi-structured questionnaire was administered to collect Bt brinjal production experiences from sub-assistant agriculture officers (SAAOs) of the DAE responsible for each of the villages selected for the qualitative fieldwork. Therefore, in total, nine KIIs were undertaken with nine SAAOs from each of the nine villages selected for the fieldwork.

- **KIIs with market traders:** To identify market traders to conduct KIIs, the types and number of market traders per village were listed, based on information from Bt brinjal farmers and SAAOs. One type of market actor from the local market chain was interviewed per village using a semi-structured questionnaire. A total of nine informants were selected to participate in these interviews.

3.4.2 Qualitative Fieldwork

Data collection for the qualitative research was undertaken from July 1-28, 2018. Prior to conducting the interviews, informed consent was collected from the participants. Table 3.6 describes the types of interviews and total informants participated in the study.

During fieldwork, audio files were uploaded daily to the server, which helped expedite data transcription and cleaning. Following completion of the fieldwork on July 28, 2018, the transcription of audio recordings was outsourced to a local qualitative research firm. Then, IFPRI's qualitative research team reviewed the transcripts, which were then outsourced to a local survey firm for translation into English. The qualitative research team prepared a code list (both Bengali and English) according to the study objectives and extracted the information from the transcripts using the qualitative analysis software NVivo Pro 11.

Table 3.6 Qualitative data collection sample and activities

Data collection activity	Description of data collection activity	Estimated time of interview	Total interviews
Activity (i). Focus group: Bt Brinjal farmers	Group interviews to collect information on Bt brinjal production and marketing experience with all Bt brinjal farmers in each of the 9 randomly selected treatment villages across 9 upazilas of the impact assessment study.	90-120 minutes per group	9 X 1 = 9
Activity (ii). Key informant interview: SAAOs	Semi-structured questionnaire will be administered to collect information on Bt brinjal production experiences from the 9 SAAOs responsible for the 9 randomly selected treatment villages across 9 upazilas of the impact assessment study.	40-60 minutes per interview	9 X 1 = 9
Activity (iii). Key informant interview: Market traders	Semi-structured questionnaire to be administered to collect information on brinjal marketing processes to at least one market actor/trader from the available local market chain from each of the 9 randomly selected treatment villages across 9 upazilas of the impact assessment study	40-60 minutes per interview	9 X 1 = 9
Estimated total number of interviews			27

Source: Constructed by authors.

4. BT BRINJAL STUDY IMPLEMENTATION

The Bt brinjal impact study was designed to provide a thorough understanding of the impact of adoption of the Bt brinjal technology, which has potential to provide important insights of the efficacy of this new technology to the Ministry of Agriculture, based on which the ministry may guide its future roll-out strategy. The study was implemented in four districts in the northwest, with 1,200 brinjal farmers—600 treatment farmers who agreed to grow Bt brinjal on 10-decimal plots (one-tenth of an acre) in winter with seedling transplanting season starting in November 2017, and 600 control farmers who agreed to grow non-Bt brinjal of the same variety (ISD-006) on 10-decimal plots.

In addition to insights from the quantitative impact results, which are elaborated in subsequent sections, documentation of the implementation processes that led to the outcomes observed is crucial. To this end, this section reviews the project partners who contributed in various ways—coordinating study activities, surveying farm households, and monitoring field-level implementation.

4.1 Project Partners

Upon request of the Government of Bangladesh and USAID, this collaborative research study brought together knowledge and technical expertise from six key project partners, whose roles are described below.

4.1.1 Bangladesh Agricultural Research Institute (BARI)

BARI is one of the agricultural research institutes under the Ministry of Agriculture, which conducts research on non-rice crops, including brinjal.

In the first week of August 2017, as advised by the Ministry of Agriculture, BARI transferred a portion of funds earmarked for the study to DAE for implementing the study. BARI certified, packaged, and supplied sufficient quantity of Bt brinjal seeds to DAE for 600 treatment farmers to grow Bt brinjal on 10-decimal plots each. BARI also supplied sufficient conventional brinjal seeds (ISD-006) for 600 control farmers each cultivating a 10-decimal plot and for the refuge border around Bt brinjal plots of treatment farmers to abide by the BARI’s biosafety rules and guidelines. Further, BARI conducted the training of trainers (ToT) for DAE officials from each of the four districts of the study, and later monitored Bt brinjal seedling production and cultivation by treatment farmers.

4.1.2 Department of Agricultural Extension (DAE)

The DAE is an agency under the Ministry of Agriculture, which provides extension services and advises to farmers allover Bangladesh.

Under this study, DAE identified and assigned sub-assistant agricultural officers (SAAOs) to each of the 200 villages selected for the study, then mobilized the selected SAAOs to participate in the ToT sessions conducted by BARI at its headquarters in Gazipur. Thereafter, DAE organized farmers' trainings for 600 treatment and 600 control farmers at the upazila-level, led by the BARI-trained SAAOs. DAE identified one lead farmer among six treatment and control farmers in each study village, resulting in 200 lead farmers. A significant part of DAE's scope of work was providing input support. Specifically, DAE collected Bt brinjal and conventional brinjal seeds from BARI and distributed these to lead farmers in the respective treatment and control villages, who then raised seedlings for the other treatment and control farmers in the villages. DAE coordinated and monitored the distribution of seedlings produced by 200 lead farmers to other five selected treatment and control farmers in each of the 200 study villages (that is, 1,000 farmers in total). During the first three and a half months of the cultivation period, he—DAE monitored Bt brinjal and conventional brinjal growth monthly, which became more frequent during the harvesting period (that is, every 15 days). All travel and daily allowance costs of SAAOs during training and monitoring visits were disbursed by DAE.

4.1.3 International Food Policy Research Institute (IFPRI)

IFPRI provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition in developing countries. Established in 1975, IFPRI currently works in over 50 countries. It is a research center of the Consultative Group on International Agricultural Research (CGIAR), a worldwide partnership engaged in agricultural research for development. IFPRI has over three decades of experience conducting evidence-based research for food and agricultural policy in Bangladesh.

IFPRI designed the Bt brinjal impact study in consultation with BARI. IFPRI focused on evaluation research, coordination between partners, and dissemination of results. IFPRI prepared the village census questionnaire, worked closely with DATA on selecting treatment and control farmers from the village census lists, and supervised the survey enumerators' training to conduct the census of the 200 selected villages (100 treatment and 100 control villages). To evaluate the impact of the intervention, IFPRI prepared baseline and endline survey questionnaires, oversaw the survey enumerators' and supervisors' training, and monitored both surveys before and after the close of the intervention. IFPRI researchers also oversaw the activities of other project partners; for example, IFPRI observed BARI's ToT to DAE officials and the farmers' training led by SAAOs. Additionally, IFPRI and DAE jointly developed a registry, which was distributed to farmers to record costs and input use on a weekly basis, and monitored that treatment and control farmers were completing the registry properly. IFPRI conducted qualitative fieldwork to glean deeper understandings of the quantitative findings; salient findings have been incorporated into this report in the relevant sections. IFPRI researchers analyzed the longitudinal data to estimate the impacts of the Bt brinjal technology, which are presented in this report.

4.1.4 Agricultural Policy Support Unit (APSU)

The Agricultural Policy Support Unit (APSU) of the Ministry of Agriculture aims to strengthen the Ministry of Agriculture's in-house policy analysis capacity by providing timely policy recommendations in response to short-term challenges; carrying out in-depth analyses to help produce policy options that will address medium- and long-term challenges; and monitoring and evaluating policy implementation and outcomes.

APSU coordinated between project partners, monitored trainings, survey administration, and all aspects of implementation throughout the duration of the study.

4.1.5 Cornell University

Cornell University is a university based in New York, United States. Under this research study, a professor from Cornell University contributed to the design of the research study, participated in monitoring visits, analyzed impacts, and coauthored the report.

4.1.6 Data Analysis and Technical Assistance (DATA)

Data Analysis and Technical Assistance (DATA) is a Bangladeshi consulting firm with expertise in conducting complex surveys and data analysis. DATA's capacity to conduct surveys to collect high quality data was largely built by IFPRI over the past two decades.

Under this study, DATA finalized the full village list and randomly selected 100 treatment and 100 control villages. DATA conducted complete census of 200 villages, and from the census list of households, DATA and IFPRI together randomly selected 600 treatment and 600 control farmers. DATA hired and trained survey enumerators to conduct the village census, and administered the baseline and endline surveys. Furthermore, DATA cleaned and documented the data prior to delivering the datasets to IFPRI for analysis.

4.2 Project Monitoring

High fidelity of study implementation is crucial to gain a better understanding of how and why an intervention works, and the extent to which outcomes can be improved. With the introduction of this new Bt brinjal technology, intensive training of DAE officials at different levels was crucial to ensure a mutual understanding across the frontline. To this end, over the course of the study, various actors have been involved in high quality monitoring—namely, APSU, BARI, DAE, and IFPRI.

4.2.1 Monitoring Training for DAE Officials

Prior to implementation of the intervention, significant activities were undertaken to prepare the DAE officials on how to properly monitor the study, as well as advise participating farmers on proper production practices for Bt brinjal and conventional brinjal.

In August 2017, BARI conducted a day-long training of trainers (ToT) for 30 DAE officials at its Gazipur headquarters premises on how to grow Bt brinjal. Subsequently, these DAE officials trained SAAOs. DAE participants from the 10 selected upazilas in four districts attended the training session. Participants included one deputy director, four additional deputy directors, four district training officers, 11 agricultural extension officers, and 10 upazila agriculture officers (UAOs). Some DAE officers from the 10 selected upazilas could not attend the training due to various reasons; therefore, BARI conducted a supplementary ToT at the DAE office in Bogra District in September 2017 where 10 DAE officials were trained on the same content.

DAE assigned 150 SAAOs to 100 treatment and 100 control villages under this study. From September 16-19, 2017, DAE held day-long training sessions in the study upazilas to train the 150 selected SAAOs on agronomic practices of cultivating Bt brinjal. From September 5-19, 2017, the trained SAAOs visited 1,200 farmers in 100 treatment and 100 control villages to confirm their involvement in the study.

Before field-level implementation started, from November 25-27, 2017, IFPRI, DAE, and BARI conducted a training for 177 DAE officials from different ranks on monitoring brinjal cultivation, which solidified a mutual understanding between the field-level agriculture extension agents and their superiors. This training covered fundamentals of entomology, how extension agents can diagnose and respond to infestation issues affecting farmers, and how to verify farmer registries—a tool developed by DAE and IFPRI for farmers to routinely record their input use, production costs, and brinjal harvesting and selling—are completed correctly. The farmers registry was intended to verify the results and triangulate the survey data, not as a primary source of data.

4.2.2 Farmers' Training

SAAOs trained all treatment and control farmers in several batches on agronomic practices of cultivating brinjal from September 20–October 1, 2018—prior to study implementation. DAE developed a manual on brinjal production, which extensively covered integrated pest management (IPM). Control farmers were trained to manage four types of pests—fruit and shoot borer, leaf hoppers/jassids, beetles, and red spiders; whereas treatment farmers were trained to manage six types of pests—white flies, thrips tabaci, aphids, leaf hoppers/jassids, beetles, and red spiders.

4.2.3 Input Packages for Farmers

As per the study protocol, the Ministry of Agriculture provided an input package to all 1,200 brinjal farmers before study implementation commenced, with funding from the Government of Bangladesh. Table 4.1 shows the items and corresponding costs of inputs provided for a 10-decimal plot. The input package excluded pesticides.

Except for seed variety—control farmers received conventional brinjal seeds (ISD-006), whereas treatment farmers received the Bt variety—all 1,200 brinjal farmers in the study received the same input package.

Table 4.1 Individual input package and cost

Items	Quantity (kg)	Unit cost (Tk per kg)	Cost (Tk)
Urea	17	16	272
Triple Super Phosphate (TSP)	17	22	374
Muriate of Potash (MoP)	10	15	150
Gypsum	7	12	84
Zinc Sulphate	1	100	100
Boric acid	1	150	150
Irrigation			350
Netting to prevent bird attack and support for plants (posts)			350
Seed sorting			150
Seed treatment			50
Total cost for 10 decimal plot			2,030

Source: Department of Agricultural Extension (DAE)

4.2.4 Seedling Production and Transplantation

There were six famers in each study village (treatment and control), one of which was randomly selected as a lead farmer to grow seedlings until maturity on behalf of the other five farmers.

During the field visit in November 2017, IFPRI researchers spoke with various lead farmers who were mostly optimistic about growing Bt brinjal (Box 4.1).

Box 4.1 Case Study on Lead Farmer in Shahjadpur Upazila: A farmer in Shahjadpur Upazila, Rajshahi Division has been identified as a treatment farmer to cultivate Bt brinjal. The lead farmer expressed his enthusiasm to participate in the research. He asserted, "I can pay Tk 30,000 cash now to buy 30,000 [Bt] seedlings." The farmer shared that he is eager to invest in growing brinjal crops that use less pesticide and will save him money in the long run.

Once the seedlings were mature, lead farmers, with the assistance of DAE, distributed the seedlings to the other treatment and control farmers to transplant the seedlings on their respective 10-decimal plots. According to BARI monitoring reports, all seedlings were taken care of and beds were properly enclaved by nets to protect seedlings from insects. Per BARI's instructions, treatment farmers included a four-sided non-Bt brinjal refuge, or boundary, to slow the development of Bt resistance. During field visits to the trial plots, BARI confirmed that refuge crop management was executed properly on Bt brinjal plots.

Although seedling production was delayed by 10-15 days due to heavy rainfall and wet field conditions in some areas, BARI indicated that most seedlings were transplanted at the optimum maturity and around the same time in all study districts. In February 2018, IFPRI researchers observed that despite slow growth of plants due to cold temperatures during the winter, brinjal plants appeared to have 'caught up' in growth with the warmer temperatures.

4.2.5 Pest Infestation

Except for fruit and shoot borer (FSB), infestation by non-target insects such as aphid, white fly, jassid, hopper, thrips and worm was observed in the Bt and non-Bt brinjal plants in all four districts. In other words, Bt brinjal was found effective against only shoot and fruit borer, as expected. A variety of pesticides, including *Malatheon*, *Asataf*, *Admire,* and *Vertimek,* were used as prescribed by DAE to control non-target pests. Other plant medications such as *Bavistin*, *Crossin*, *Nativo,* and *Kaisin*, were used as prescribed to control wilting of the seedling.

4.2.6 Flowering of Plants

During monitoring visits, BARI scientists found that Bt brinjal yields consistently outperformed conventional brinjal crops across all study districts.

During the qualitative research, some farmers reported that they were satisfied with the Bt brinjal fruit color, texture, and size, but were disappointed with the late bearing of flowers and fruit, which in turn brought about lower market prices due to the delayed harvest and the higher supply of brinjal in the market. In these areas, farmers and agriculture extension officials suggested that shifting production earlier or later, when there is lower supply of brinjal in the market, may increase demand and profits for Bt brinjal.

Most farmers, however, reported that they were happy with the relatively higher yield of Bt brinjal compared to local brinjal.

5. PROFILE OF SURVEY HOUSEHOLDS

5.1 Introduction

Using the 2017 baseline household survey data, this section provides the profile of survey farm households of the treatment farmers who were willing to grow Bt brinjal and the control farmers who would grow the conventional brinjal variety, as they had cultivated previously. The findings in this section portray the situation of households just before study implementation. Since a randomized controlled trial design was used to assign farmers to treatment and control groups, similarity in household characteristics are expected across all groups at the start of the intervention.

This section opens by providing the household and individual characteristics of surveyed households at baseline, including household size, education, and occupation, followed by greater detail about household infrastructure and assets. The section closes with information on the land tenure arrangements and share of crops on total cropped land.

5.2 Characteristics of Survey Households

Table 5.1 shows household characteristics of the Bt brinjal sample. The average household size is 4.6, which is relatively consistent between treatment and control. The dependency ratio is the ratio (expressed as a percentage) of people in the household who are considered dependent (ages 0-14 and above 60) to the number of working age household members (ages 15-60). The dependency ratio does not vary significantly across treatment arms, ranging from 56.5 to 59.0 percent.

Given the nature of the research design, in which we purposively selected geographic areas with a high concentration of brinjal farmers and enrolled brinjal farmers into the study sample, it is unsurprising that farming is the main occupation for most surveyed households (84.1 percent), followed by business and trade (9.1 percent of treatment households and 7.9 percent of control households).

Males and females older than age 15 have an average of 6.3 years of schooling. Adult males and females with no schooling make up 23.6 and 29.5 percent of the sample, respectively, with minimal variation between treatment and control groups.

Table 5.1 Characteristics of Survey Household

Item	Treatment	Control	All
Household size (number)	4.7	4.5	4.6
Dependency ratio (percent)	56.5	59.0	57.7
Primary school-age children (6-11 years) who never went to school (percent)	2.5	3.3	2.9
Secondary school-age children (12-18 years) who never went to school (percent)	1.5	0.8	1.2
Years of schooling, male household head	5.5	5.3	5.4
Years of schooling, wife of household head	5.2	5.0	5.1
Years of schooling, adult male aged 15 and above	6.9	6.7	6.8
Years of schooling, adult female aged 15 and above	6.0	5.6	5.8
No schooling, adult male (percent)	22.9	24.3	23.6
No schooling, adult female (percent)	28.8	30.2	29.5
Principal occupation of household head (percent)			
Agricultural day laborer	1.5	0.7	1.1
Nonagricultural day labor	0.8	0.5	0.7
Salaried	1.3	2.2	1.8
Self Employed	2.2	1.5	1.9
Business/Trade	9.1	7.9	8.5
Farming	82.5	85.7	84.1
Non-earning occupations	1.8	0.8	1.3
Total	100.0	100.0	100.0

Source: 2017 baseline survey for Bt Brinjal Impact Evaluation, IFPRI.

Next, we look at the status of electricity, and then dwelling type of surveyed households (Table 5.2). In the absence of reliable income data in Bangladesh, household characteristics such as electricity and dwelling structure are often used as proxy indicators for socioeconomic status of households by a number of government safety net programs as eligibility criteria to target the poor in Bangladesh.

Most surveyed farmers (81.6 percent) have access to electricity. Additionally, Ahmed and Tauseef (2018) find that access to electricity is a key factor in preventing households from backsliding into poverty, and helping households climb out of chronic poverty in rural Bangladesh. Nearly all (95.1 percent) surveyed households live in households with roof made of tin.

Table 5.2 Electricity and structure of dwelling

Characteristics	Treatment	Control	All
		(percent)	
Household has electricity	82.4	80.8	81.6
Structure of walls			
Permanent*	84.7	89.2	87.0
Roofing material			
Concrete/brick	5.6	3.7	4.6
Tin	94.1	96.1	95.1
Other	0.3	0.2	0.3

Source: 2017 baseline survey for Bt Brinjal Impact Evaluation, IFPRI.
*Permanent materials include field bricks, concrete, wood and tin sheets.

Table 5.3 features the types of latrines used by surveyed households. Over one-half (57.1 percent) of all households use a sanitary latrine without a flush, followed by a *pucca* (unsealed) toilet. There is nearly zero open defecation in the survey sample, with only 1.7 percent of households having no identified latrine at baseline.

Table 5.3 Types of latrines

Item	Treatment	Control	All
		(percent)	
None (open field)	2.4	1.0	1.7
Kutcha (fixed place)	3.9	4.4	4.1
Pucca (unsealed)	35.0	36.2	35.6
Sanitary without flush	56.0	58.3	57.1
Sanitary with flush	2.5	0.2	1.4
Community latrine	0.2	0.0	0.1
Other	0.2	0.0	0.1
Total	100.0	100.0	100.0

Source: 2017 baseline survey for Bt Brinjal Impact Evaluation, IFPRI.

Next, we explore ownership status of selected assets across surveyed households, categorized by consumption and productive assets (Table 5.4). Mobile phone ownership is nearly universal (98.1 percent). With the growth of digital agricultural extension services, mobile phones have emerged as an important tool for farmers to receive agriculture extension messages. About three-fourths (76.2 percent) of surveyed farmers own a bicycle, which agrees with quantitative findings and focus group discussions with treatment farmers indicating that bicycle is one of the modes of transport for bringing crops to the market (Table 8.1).

About one-half (48.1 percent) of households own a fishing net and 83.9 percent own a cow, signifying farmers' participation in crop *and* non-crop agricultural activities, such as livestock and fisheries.

About 80 percent (80.8 percent) of all surveyed households own a pesticide sprayer, which is unsurprising given brinjal's susceptibility to pest infestations. About one-quarter (24.7 percent) of surveyed farmers own plough and yoke.

Land is the most important factor in agricultural production. In Bangladesh, land tenure arrangements represent a major determinant of socioeconomic status and technology adoption. Now, we delve into the land tenure arrangements of the surveyed brinjal farmers (Table 5.5).

The dominant tenurial arrangement in Bangladesh is sharecropping, where the produce is shared between the cultivator and the landowner in different proportions that have been agreed upon prior to cultivation. Nearly one-half of surveyed farmers are sharecroppers (46.7 percent of treatment farmers and 44.1 percent of control farmers). This group of sharecroppers includes those who do not own any cultivable land (that is, pure tenant), as well as those who own land and sharecrop others' land. Cash lease is also a common land tenure arrangement among the surveyed farmers (10 and 13.1 percent of treatment and control farmers respectively), either as pure tenants or as those with their own land plus cash-leased land. The proportion of farmers with mixed-tenancy arrangements (operating sharecropped plus cash-leased land, either as pure tenants or landowners) is around 45 percent. Around 48 percent of treatment farmers and control farmers cultivate their own lands.

Table 5.4 Household asset ownership

Asset	Treatment	Control	All
		(percent)	
Consumer Assets			
Electric fan	85.4	82.8	84.1
Radio	1.0	0.7	0.8
Audio cassette/CD player	0.5	1.0	0.8
Television (B/W)	3.4	3.9	3.6
Television (color)	40.2	39.4	39.8
Sewing machine	9.6	8.2	8.9
Bicycle	75.5	76.9	76.2
Rickshaw	0.3	0.7	0.5
Boat	0.2	0.2	0.2
Motorcycle	16.5	12.0	14.2
Mobile phone set (functioning)	98.2	98.1	98.1
Fishing net	47.7	48.5	48.1
Solar energy panel	15.3	16.3	15.8
Hand tubewell	23.4	23.7	23.6
Cow	83.4	84.3	83.9
Buffalo	0.7	0.0	0.3
Goat/sheep	45.7	46.1	45.9
Duck/hen	87.7	88.4	88.1
Productive Assets			
Plough and yoke	25.9	23.6	24.7
Pesticide sprayer	77.8	83.8	80.8
Equipment for showering plant (Jhorna/Jhajhara)	10.6	7.6	9.1
Net for covering field/seedbed	15.0	11.8	13.4
Insect trap (Pheromone trap)	4.7	3.5	4.1
Jerry can (container) for mixing pesticide	11.4	8.1	9.8
Wheelbarrow	0.5	0.0	0.3
Tractor	0.3	0.5	0.4
Power tiller	9.4	10.6	10.0
Thresher	17.0	19.7	18.3
Swing basket	8.1	5.6	6.8
Don	1.2	0.7	0.9
Low lift pump (LLP) for irrigation	13.5	14.5	14.0
Shallow tubewell (STW)	32.3	33.3	32.8
Deep tubewell (DTW)	0.5	0.3	0.4
Electric motor pump	5.4	4.9	5.1
Diesel motor pump	2.9	5.2	4.0
Seeder Drills: till, plant, fertilize simultaneously	0.0	0.0	0.0

Source: 2017 Baseline survey for Bt Brinjal Impact Evaluation, IFPRI.

Table 5.5 Land tenure arrangements

	Treatment	Control
	(percent)	
Pure tenant	6.2	6.7
Sharecropping	62.2	65.0
Cash lease	27.0	15.0
Both	10.8	20.0
Own land	47.9	48.5
Mixed tenant	45.9	44.8
Sharecropping	83.5	75.9
Cash lease	8.1	14.3
Both	8.5	9.8
All sharecroppers	46.7	44.1
All cash lease	10.0	13.1

Source: 2017 baseline survey for Bt Brinjal Impact Evaluation, IFPRI.

Lastly, we explore share of crops on total cropped land among surveyed farm households at baseline (Table 5.6). Despite being identified as brinjal farmers for this study, brinjal occupies only 10 percent of total cropped area for surveyed farmers (9.5 percent and 10.7 percent for treatment and control farmers, respectively). Instead, we see that over one-half of total cropped area was under rice (63.1 percent and 57.2 percent for treatment and control farmers, respectively), with nearly all farmers having cultivated rice at baseline (93.6 percent of treatment farmers vs. 92.1 percent of control farmers)—a mainstay of the Bangladeshi diet. Besides brinjal and rice, farmers diversified agriculture production into other non-rice crops, too. For instance, about one-fifth of surveyed farmers cultivated maize, which is mainly used for fish and livestock feed in Bangladesh. Farmers also cultivated a variety of other high value vegetables, fruits, and spices, including potatoes, jute, chili, patal, bittergourd, and arum, and other leafy vegetables.

Table 5.6 Share of crops on total cropped land at baseline

	Farmers who grew this crop		Total cropped area under this crop	
Crop	**Treatment**	**Control**	**Treatment**	**Control**
		(percent)		
Rice	93.6	92.1	63.1	57.2
Wheat	5.5	2.7	0.7	0.4
Maize	20.7	21.9	3.9	3.9
Pulse	4.0	2.5	0.3	0.2
Oilseed	5.5	3.9	0.6	0.5
Potato	40.3	42.6	6.1	6.5
Brinjal	99.2	99.3	9.5	10.7
Patal	14.1	18.4	1.6	1.9
Bittergourd	8.6	11.6	1.2	1.6
Arum	10.9	10.3	0.9	0.9
Bean	5.2	9.4	0.5	1.1
Other vegetable	19.5	30.8	2.8	4.3
Leafy vegetable	9.9	11.4	1.1	1.6
Banana	8.7	14.8	1.2	2.5
Other fruit	1.7	0.5	0.2	0.0
Onion	7.9	5.2	0.5	0.4
Chili	14.6	18.5	1.3	1.7
Other spice	10.4	10.6	0.8	1.0
Jute	18.2	16.7	2.4	2.0
Other crops	10.3	11.3	1.6	1.8

Source: 2017 baseline survey for Bt Brinjal Impact Evaluation, IFPRI.

5.3 Summary

In this section, we developed a better sense of the baseline situation of study farmers prior to study implementation. By and large, we see that brinjal farmers primarily engage in farming, and secondarily business and trade. Despite being identified primarily as brinjal farmers under this study, we see that these farmers, in fact, engage in a rich portfolio of crop and non-crop agricultural activities, as drawn from the share of total cropped land and owned assets.

Most farmers have access to electricity and mobile phones, with a growing body of evidence suggesting that both are critical factors in preventing households from falling into poverty and helping to move out of poverty (Ahmed and Tauseef 2018).

Land tenure arrangements influence farmers’ decision-making on agricultural production practices. While nearly half of surveyed farmers own land, there is a share of tenant farmers who may be more risk adverse, and thereby less likely to adopt improved agricultural technologies, whether this be farm mechanization or modern seed varieties.

6. IMPACTS OF BT BRINJAL: PEST INFESTATION AND INSECTICIDE USE

6.1 Introduction

Bt Brinjal (BARI Bt Begun 4) was developed to resist the fruit and shoot borer (FSB) pest. This resistance means that farmers should be able to grow Bt brinjal with fewer applications of pesticides. In this section, we assess whether it meets both goals. Section 6.2 provides descriptive statistics on pest infestations and insecticide use. Section 6.3 reports on our impact estimates. Section 6.4 explores the impact on the toxicity of pesticides that are applied and section 6.5 summarizes.

6.2 Pests and Insecticides

At both baseline and endline, farmers were asked about the prevalence and extent of damage due to pests. Tables 6.1 and 6.2 provide basic data on this.

The left-hand side of Table 6.1 tells us that at baseline, fruit and shoot borer was a universal problem for both treatment and control farmers, with more than 98 percent of plots in both groups affected by this pest. Other types of pest infestations–leaf eating beetles, thrips, white flies, jassids, aphids, mites, leaf bugs and leaf rollers–were also widespread, with prevalences ranging from 40-47 percent (mites, leaf bugs, and leaf rollers) to 80-81 percent (leaf-eating beetles). There are no meaningful differences in these prevalences across treatment and control farmers. The left-hand side of Table 6.2 tells us that at baseline, conditional on experiencing an infestation, just over a third of plants (35-36 percent) were affected by fruit and shoot borer and around 25-29 percent were affected by other pests. Again, there are no meaningful differences across treatment and control farmers.

Table 6.1 Percentage of plots infested by pests

	Baseline		Endline	
Name of pest	Treatment (n=631)	Control (n=628)	Treatment (n=603)	Control (n=589)
Fruit and shoot borer	98.4	98.9	10.6	90.3
Leaf eating beetles	81.6	80.4	47.1	63.7
Thrips, white fly, jassid or aphids	66.6	67.4	49.3	57.7
Mites, mealy or leaf wing bugs or leaf roller	40.7	47.1	35.7	46.7

n: number of plots in the sample.

Source: 2017 baseline and 2018 endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Table 6.2 Percentage of plants affected by pests in pest-infested plots, conditional on any damage being observed

	Baseline		Endline	
	Treatment	Control	Treatment	Control
Name of Pest				
Fruit and shoot borer	35.5	36.4	17.2	37.5
Leaf eating beetles	26.6	28.5	18.5	24.8
Thrips, white fly, jassid or aphids	24.7	28.3	18.4	24.7
Mites, mealy or leaf wing bugs or leaf roller	26.8	29.2	17.6	28.1

Source: 2017 baseline and 2018 endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

The right-hand panels of Tables 6.1 and 6.2 provide endline prevalences and the extent of damage from pests. Among farmers randomized into growing Bt brinjal, the percentage of farmers reporting damage from fruit and shoot borer falls to 10.6 percent, a massive 87.8 *percentage point* reduction. Among the few Bt brinjal farmers who report fruit and shoot borer damage, on average they report at endline that 17.2 percent of their plants were affected; this is half the figure (35.5 percent) reported at baseline (Table 6.2). Putting all these data together, the percentage of Bt brinjal farmers' plants affected by fruit and shoot borer falls from 34.9 percent (35.5 *x* 98.4 percent) to 1.8 percent (17.2 *x* 10.6 percent). By contrast, there is a much smaller change for all farmers growing ISD-006; the percentage of their plants affected by fruit and shoot borer falls from 36.0 percent (36.4 *x* 98.9 percent) to 33.9 percent (37.5 *x* 90.3 percent).

During a focus group discussion, a treatment farmer noted that Bt brinjal was less vulnerable to pests compared to the local brinjal variety:

> *By the grace of Allah, the Bt brinjal you gave us from the office was far better than the local variety. From 4 maunds (160 kg) of local brinjal, we find significant loss due to pest infestation. But that doesn't happen in Bt. That's a huge savings.*
> –Bt brinjal farmer, Pirgonj Upazila, Rangpur District

The descriptive statistics in Table 6.1 also show that infestation of secondary pests–leaf eating beetles, thrips, white flies, jassids, aphids, mites, leaf bugs, and leaf rollers–fall for both treatment and control farmers at endline compared to their baseline infestation rates and for some pests, the percentage of fruit affected also drops. Several factors may be responsible for these decreases in secondary pest infestations at endline:

- The DAE provided training to all treatment and control farmers on Integrated pest management (IPM), where they were given instruction on preventive and combative pest infestation measures. Additionally, inputs such as yellow sticky traps were provided to all treatment and control farmers by the DAE. It is possible that greater use of IPM along with these traps contributed to reduced secondary pest infestation for both groups at the endline.

- BT-4 and ISD-006 are both BARI engineered varieties. Neither of these varieties were grown by farmers at baseline. It is possible that these varieties generally attract fewer pests compared to varieties that farmers usually grow.
- Temperature during the endline winter season was unusually lower than the baseline winter season. Pest infestation is likely to be lower in colder weather.

In Table 6.3, we turn our attention to pesticide use by treatment and control farmers. At baseline, farmers sprayed 29 (treatment) to 33 times (control) for all pests. Fruit and shoot borer accounted for a large share of these sprays, with treatment farmers spraying, on average 11 times and control farmers spraying 12.8 times. At endline, treatment farmers sprayed only 13.9 times, a 53 percent reduction, with much of this reduction coming from reduced spraying for fruit and shoot borer. Control households also reduced their number of sprays, possibly for the reasons described above (greater use of IPM, but the reduction in number of sprays is smaller than that observed for treatment farmers).

Table 6.3 Number of times pesticides were applied

	Baseline		**Endline**	
Average number of sprays	**BT-Brinjal (Treatment)**	**ISD-006 (Control)**	**BT-Brinjal (Treatment)**	**ISD-006 (Control)**
	(n=630)	**(n=628)**	**(n=603)**	**(n=589)**
All pests including fruit and shoot borer	29.6	33.5	13.9	21.5
Only fruit and shoot borer	11.0	12.8	1.4	7.7

n: number of plots.
Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Table 6.4 examines trends in the quantity of pesticides applied, expressed as grams (gm) or milliliters (ml) per hectare. At baseline, treatment households applied 17,948 ml or gm of pesticides per hectare, and the control households applied 20,587.7 ml or gm of pesticides per hectare, with quantities applied for fruit and shoot borer accounting for about a third of these amounts. At endline, treatment farmers had reduced the quantity of pesticide they had sprayed, with much of this resulting from reduced use of sprays for fruit and shoot borer. By contrast, there was little change in the quantity of pesticides applied by control farmers. We see a similar pattern when we look at the costs of applying these pesticides (Table 6.5).

Table 6.4 Quantity of pesticides used

Quantity (gm or ml per hectare)	Baseline		Endline	
	BT-Brinjal (Treatment)	ISD-006 (Control)	BT-Brinjal (Treatment)	ISD-006 (Control)
	(n=630)	(n=628)	(n=603)	(n=589)
All pests including fruit and shoot borer	17,948.0	20,587.7	11,450.6	16,270.0
Only fruit and shoot borer	6,384.7	7,163.5	1,025.1	5,099.4

n: number of plots
Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Table 6.5 Cost of pesticides used

Cost (taka per hectare)	Baseline		Endline	
	BT-Brinjal (Treatment)	ISD-006 (Control)	BT-Brinjal (Treatment)	ISD-006 (Control)
	(n=630)	(n=628)	(n=603)	(n=589)
All pests including fruit and shoot borer	26,986.8	29,865.4	14,417.8	21,713.8
Only fruit and shoot borer	9,980.3	10,684.6	1,233.9	7,669.9

n: number of plots
Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Bt brinjal farmers during focus group discussions stated that Bt brinjal required less pesticide than local brinjal varieties, which, in turn, led to increased savings. Similarly, during a key informant interview, an agriculture extension agent echoed that Bt brinjal required less pesticide compared to conventional brinjal: “Since this brinjal is free of *Majra poka* (fruit and shoot borer), the costing of medicine spraying is reduced a lot, so farmers are eager to grow [Bt brinjal].” Similarly, another treatment farmer in Mithapukur Upazila, Rangpur District remarked, “The good characteristic of BT brinjal is that blowfly does not attack this crop. Although some poison [pesticide] is still needed to control other pests, insect infestations on Bt brinjal is much less compared to *deshi* (local) brinjal.”

Treatment farmers in Dhamoirhat Upazila, Naogaon District echoed these findings, indicating that while Bt brinjal resists fruit and shoot borer, it was susceptible to other pests, such as white bee and white fly. During focus group discussions, treatment farmers mentioned that negative impacts from these other pests were considerably minimized by using other medicines and yellow sticky traps, which were provided to control and treatment farmers alike.

Therefore, we observe that Bt brinjal's unique characteristic of resisting fruit and shoot borer combined with the application of improved agricultural production practices such as yellow traps and other minimal insecticides to control other pests protected the plants from pest infestation, thereby reducing pesticide-related costs for treatment farmers who cultivated Bt brinjal.

6.3 Impact Analysis

We now turn to our ANCOVA model to formally assess the impact of Bt brinjal on pesticide use. We begin, in Table 6.6, with our pre-specified primary outcome, pesticide cost per ha of brinjal cultivated.

Column (1) shows that farmers growing Bt brinjal spent Tk 7,174.6 less on pesticides per hectare, compared to control farmers. When we control for selected baseline characteristics, we get a nearly identical figure, Tk 7,196.3 per hectare. This impact is statistically significant at the 1 percent level. Bt brinjal farmers reduced the number of sprays by 7.4 (column 4) and the quantity of pesticide sprayed by 4,616.7 gm (ml) per hectare. These impacts are statistically significant at the 1 percent level.

Table 6.6 Impact of Bt brinjal cultivation on use of pesticides

Outcome	(1) Cost of pesticides used (TK per ha)	(2) Cost of pesticides used (TK per ha)	(3) Number of pesticide applications	(4) Number of pesticide applications	(5) Quantity of pesticides used (ml or gm per ha)	(6) Quantity of pesticides used (ml or gm per ha)
Treatment: Bt brinjal	-7,174.6***	-7,196.3***	-7.32***	-7.37***	-4,669.5***	-4,616.7***
	(1,213.3)	(1,209.7)	(1.23)	(1.22)	(1,101.6)	(1,093.7)
Controls						
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes
Observations	1,166	1,166	1,166	1,166	1,166	1,166

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Notes: Individual characteristics are age, sex and relationship to household head. Household characteristics include characteristics of the individual responsible for brinjal production (age, education, years working as a farmer), land operated by the household and household wealth index derived from principal components (using number of rooms in the dwelling; whether the dwelling has electricity; physical states of the dwelling and ownership of the following consumer durables: wrist watch, color tv, bicycle, tri van, motorcycle and solar panels). Standard errors clustered at the village level. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level. Source: 2017 Baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

6.4 Impact on the Toxicity Level of Pesticides Used

Farmers surveyed for this study were asked to name the pesticides used for different brinjal pests. From these records, we traced information on the level of toxicity of the pesticides that are popularly used against common brinjal pests. This section describes the toxicity analyses of commonly used pesticides in brinjal cultivation and the changes detected in the use of toxic pesticides by treatment farmers.

From the baseline and endline survey data, we identified the pests that farmers applied pesticides against the most. These pests were then grouped into three categories: (1) fruit and shoot borer; (2) white flies and white insects; and (3) beetles, spiders and worms. The farmers were also asked to name the pesticides used for different brinjal pests. For each category of pest, we identified the pesticides that were most popularly used by the farmers. The trade names of these pesticides (as reported by farmers) were then matched with the *DAE List of Registered Agricultural Bio Pesticides and Public Health Pesticides in Bangladesh* (DAE 2016) to obtain their respective chemical names. Next, we consulted the *Globally Harmonized System (GHS) Acute Toxicity Hazard Categories* (United Nations 2011) to check the toxicity levels of the chemicals of these popularly used pesticides. GHS toxicity classification is an internationally recognized classification and labeling scheme of chemical substances and mixtures of chemicals according to their physical, health and environmental hazards (United Nations 2011). Combining information primarily from these two sources, we compiled a list of pesticides widely used against common brinjal pests, along with information on DAE's recommendation for which types of pests and crops they are appropriate for and their GHS toxicity classification. The information is presented in Tables 6.7 and 6.8.

Table 6.7 Globally Harmonized System of Classification and Labelling of Chemical (GHS)

Categories	Oral Hazard Statement	Dermal Hazard Statement	Inhalation Hazard Statement
1	Fatal if swallowed	Fatal in contact with skin	Fatal if inhaled
2	Fatal if swallowed	Fatal in contact with skin	Fatal if inhaled
3	Toxic if swallowed	Toxic in contact with skin	Toxic if inhaled
4	Harmful if swallowed	Harmful in contact with skin	Harmful if inhaled
5	May be harmful if swallowed	May be harmful in contact with skin	May be harmful if inhaled

Source: United Nations 2011.

Table 6.8 Features of popular pesticides used against common brinjal pests

Trade/ Brand Name	Generic/ Chemical Name	Name of Registration Holder	Recommended Crops	Recommended Pests	GHS Hazard Classification
Actara (25 WG)	Thiamethoxam	Syngenta Bangladesh Limited	Rice, Cotton, Sugarcane, Mango, Mustard, Banana, Tea, Brinjal, Marigold	BPH, Aphid, Jassid, Termite, Hopper, Beetle, Helopeltis	4 (Oral)
Alba (1.8 EC)	Abamectin	SAMP Limited	Rice	Brown Planthopper (BPH), Hispa	2 (Oral); 1 (Inhalation)
Basuden (10 GR)	Diazinon Organophosphate	Raven Agro Chemicals Limited	Tea	Aphid	4 (Oral)
Dursban (20 EC)	Chlorpyrifos Organophosphate	Auto Crop Care Limited	Rice, Tea, Potato, Cotton and Sugarcane	BPH, Hispa, Stem Borer (SB), Leafroller (LR), Grasshopper (GH), Rice bug, Termite, Cutworm, Bollworm, Aphid, Jassid	3 (Oral); 3 (Dermal); 4 (Inhalation)
Furadan (5G)	Carbofuran	Padma Oil Company Limited	Rice, Sugarcane, Potato	Stemborer, BPH, Ufra Nematode, White grub, Top and Early Shoot borer, Cutworm	2 (Oral); 2 (Inhalation)
Guilder (5 SG)	Emamectin Benzoate	Aama Gree Care	Bean, Tea	Pod borer, Termite	3 (Oral); 4 (Dermal)
Imitaf (20 SL)	Imidacloprid	Auto Crop Care Limited	Rice, Cotton, Tea, Sugarcane	BPH, Hispa, Aphid, Jassid, Whitefly, Bollworm, Termite	4 (Oral)
Licar (1.8 EC)	Abamectin	Corbel International Limited	Rice	BPH, Hispa	2 (Oral); 1 (Inhalation)
Pegasus (500 SC)	Diafenthiuron	Polo/Pegasus	Cotton, Vegetables	Whitefly, mites, aphids, jassids	4 (Oral); 3 (Inhalation); 2 (Dermal)
Ripcord (10 EC)	Cypermethrin	BASF Bangladesh Limited	Cotton, Mango, Jute, Brinjal	Bollworm, Hopper, Hairy caterpillar, Field cricket, Semilooper, Shoot and fruit borer	3 (Oral); 4 (Inhalation); 1 (Skin Sensitization)
Shobicron (425 EC)	Profenofos (40%) + Cypermthrin (2.5%)	Syngenta Bangladesh Limited	Teasel & Bitter Gourd, Brinjal, Guava, Cotton, Mango, Banana	Fruit fly, Shoot and Fruit Borer, White fly, Aphid, Jassid, Bollworm, Hopper, Beetle	Profenofos: 4 (Oral); 4 (Dermal); Cypermethrin: 3 (Oral); 4 (Inhalation); 1 (Skin Sensitization)

Table 6.8 Features of popular pesticides used against common brinjal pests *(continued)*

Tundra (20 SP)	Acetamiprid	Auto Crop Care Limited	Bean, Cotton	Aphid, Jassid, White fly	4 (Oral); 2 (Inhalation)
Vertimec (1.8 EC)	Abamectin	Syngenta Bangladesh Limited	Tea, Brinjal, Jujube, Litchi	Red spider mite, mite	2 (Oral); 1 (Inhalation)
Volium Flexi (300 SC)	Thiamethoxam (20%) + Chloraniliprole (20%)	Syngenta Bangladesh Limited	Tomato, Brinjal	Fruit borer, Shoot and fruit borer	4 (Oral); The toxicological properties have not been thoroughly investigated for Chloraniliprole
Wonder (5 WG)	Emamectin Benzoate	Asia Trade International	Cotton	Bollworm	3 (Oral); 4 (Dermal)

Sources: WHO (2010); United Nations (2011); DAE (2016).

Table 6.9 summarizes the quantity and prevalence of use of pesticides described in Table 6.8 at both baseline and endline periods: the percentage of total brinjal plots that used the selected pesticides and the quantity applied (ml or gm) per hectare of those insecticides, disaggregated by treatment and control status. The data are disaggregated according to three categories of brinjal pests described above.

Table 6.9 Popular pesticides used for common pests

	Percentage of total plots that used this pesticide for fruit and shoot borer				Quantity (ml or gm) per hectare			
	Baseline		Endline		Baseline		Endline	
Name of Pesticides	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Popular Pesticides for Fruit and Shoot Borer Infestation								
Actara	3.5	3.5	1.2	5.8	85.1	53.8	14.3	96.9
Alba	15.4	12.6	2.5	9.3	1,270.0	1,506.0	76.8	376.5
Dursban	7.9	6.5	2.8	8.3	247.2	174.6	66.1	269.4
Guilder	1.1	3.5	1.2	8.0	22.5	105.7	42.1	286.4
Ripcord	13.3	14.0	1.3	5.4	545.5	914.7	34.0	233.4
Shobicron	3.8	3.2	2.7	4.9	209.0	139.1	98.7	167.8
Volium	4.0	5.1	0.3	3.4	93.0	218.7	6.2	105.0
Wonder	3.8	5.6	0.2	6.1	136.8	176.0	3.1	189.4
Popular Pesticides for White Flies/White Insects								
Actara	3.2	6.7	3.8	5.3	85.1	128.5	51.2	88.0
Alba	4.4	1.3	2.5	2.9	222.9	85.4	76.5	108.2
Dursban	5.1	4.1	6.0	3.9	168.8	110.4	146.7	124.4
Imitaf	1.4	1.8	7.8	2.2	92.4	87.3	405.8	110.8
Ripcord	5.2	5.1	5.3	5.3	249.0	107.5	175.6	155.0
Shobicron	5.4	4.6	2.7	3.7	248.2	216.9	79.4	156.2
Tundra	4.8	4.9	6.5	4.9	214.9	215.1	133.7	166.8
Pegasus	Not used in baseline		5.1	1.0	Not used in baseline		163.0	23.4
Popular Pesticides for Beetles, Spiders and Worms								
Actara	1.8	3.2	4.3	6.6	17.8	58.8	73.5	130.8
Alba	2.7	0.6	5.5	3.6	220.2	16.6	137.3	234.0
Basudin	1.9	1.9	1.2	1.2	274.1	293.0	169.5	266.4
Dursban	5.2	4.6	2.5	3.4	281.2	228.7	94.1	177.3
Furadan	1.6	2.6	3.7	3.6	187.3	276.2	862.7	864.1
Licar	1.9	3.5	3.8	6.5	140.9	130.1	124.2	239.9
Ripcord	2.4	2.2	2.0	3.4	99.1	60.8	55.7	90.0
Shobicron	1.6	3.2	0.8	1.5	150.1	224.2	26.1	59.8
Vertimec	3.0	4.3	4.3	9.0	182.7	274.0	137.7	338.6
Pegasus	Not used in baseline		4.8	1.5	Not used in baseline		122.4	34.5

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

The prevalence of use of pesticides commonly applied against fruit and shoot borer declined in treatment plots between baseline and endline periods for all selected brands. The prevalence of use of these popular pesticides is lower in treatment plots compared to control plots at the endline. Similarly, the quantity (ml or gm) of pesticides used per hectare against fruit and shoot borer also fell between baseline and endline periods in treatment plots, and quantities used in treatment plots are lower compared control plots in the endline. Alba 1.8 EC, Dursban 20 EC, and Ripcord 10 EC are the three pesticides most popularly used against FSB. Although Alba 1.8 EC is the one of the most widely-used pesticides (not only against FSB but other common pests as well), it is extremely noxious. The GHS hazard scale of the chemical component of this pesticide, Abamectin, indicates that it is fatal to inhale and ingest. The use of this dangerous pesticide against FSB dropped from 15.4 percent in baseline to 2.5 percent in endline among treatment plots, and the quantity also fell from 1,270.0 in the baseline to only 76.8 ml or gm per hectares in the endline. The prevalence of use of selected pesticides for fruit and shoot borer among control plots between baseline and endline is less consistent, with the use of some pesticides increasing and others decreasing between the two periods.

Use of pesticides against secondary pests changed sporadically for both treatment and control plots between baseline and endline. Overall, farmers tend to use pesticides that have oral and inhaled hazard scale between 3 and 4. Exceptions include the use of Alba 1.8 EC, Licar 1.8 EC, Furadan 5G and Vertimec 1.8 EC, which are classified as fatal in the GHS toxicity scale and yet are still quite widely used by farmers. The use of these pesticides is largely influenced by market availability and promotions and farmers are rarely informed about their toxicity properties.

One way of summarizing these data is to group their prevalence and use by the GHS Oral Hazard classification.[6] The information is presented in Table 6.10. This shows that fewer treatment farmers were applying pesticides of high toxicity levels (levels 2 and 3) compared to control farmers at endline. The mean number of times highly toxic (levels 2 and 3) pesticides were applied during the endline season was also lower for treatment farmers compared to the control farmers. The use of pesticides against fruit and shoot borer is lower among treatment farmers compared to control farmers for all toxicity classifications at endline and is also lower compared to treatment farmers' usage in baseline. The mean number of times pesticides were applied for fruit and shoot borer by treatment farmers is also lower compared to their control counterparts in the endline and lower compared to quantities applied by treatment farmers in the baseline.

[6] Although the inhalation hazard classification would have been more appropriate, this information is not available for all the pesticides identified during our surveys.

Table 6.10 Disaggregation of pesticide toxicity

Toxicity Scale	Frequency				Mean Sprays			
	Baseline		Endline		Baseline		Endline	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Pesticides used for all pests								
1	N/A*				N/A			
2	31.4	34.1	34.2	43.0	3.8	4.1	1.7	3.1
3	45.7	46.7	28.0	45.2	4.1	5.2	1.7	3.5
3.5 (avg. scale)	11.8	10.8	6.8	11.2	1.2	1.0	0.4	0.8
4	32.2	36.2	43.8	42.8	3.0	3.8	3.5	3.0
5	N/A				N/A			
Pesticides used for fruit and shoot borer								
1	N/A*				N/A			
2	17.8	17.0	5.1	14.1	2.0	2.5	0.2	0.9
3	24.3	26.4	5.3	24.6	1.8	2.6	0.2	1.7
3.5 (avg. scale)	3.8	3.2	2.7	4.9	0.3	0.2	0.1	0.3
4	9.7	11.0	5.5	13.8	0.6	0.8	0.3	0.9
5	N/A				N/A			

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
*N/A indicates that none of the pesticides selected for this analysis corresponded to the respective toxicity scale
Toxicity scale is based on GHS Oral Ingestion Hazard level
Frequency: Percentage of farmers using pesticides of corresponding toxicity level
Mean Sprays: Average number of times pesticides of corresponding toxicity level were applied
Analysis is based on a select few pesticides which have been identified as most popularly used by farmers

We summarize these data by constructing a toxicity score, the Pesticide Use Toxicity Score (PUTS). PUTS assigns a score based on the GHS Oral Hazard category of the selected pesticides and the frequency of use of the respective pesticides. In the GHS Hazard Classification scale, lower levels (1,2) correspond to more severe levels of toxicity. For PUTS to be easily interpretable, we invert the GHS scale so that higher values correspond to higher toxicity levels. The toxicity score was calculated in the following method:

$$PUTS = Inversed\ GHS\ Oral\ Hazard\ Classification \times Number\ of\ times\ the\ respective\ pesticide\ was\ applied\ in\ a\ season$$

Summary statistics are shown in Table 6.11 below. This shows that average toxicity score for treatment farmers is much lower than that of control farmers in the endline; at baseline, they were approximately equal. There are two possible explanations for this decrease in average: (i) treatment farmers are applying pesticides less frequently compared to control farmers and (ii) treatment farmers are using less harmful pesticides compared to control farmers. The disaggregation in Table 6.10 above suggests that this difference arises largely from treatment farmers applying toxic pesticides less often compared to control farmers.

Table 6.11 Pesticide use toxicity score (PUTS) summary statistics

	Baseline		Endline	
	Treatment	**Control**	**Treatment**	**Control**
Mean	22.3	24.5	9.5	17.0
St. Dev.	29.4	32.5	14.1	23.2
Min	0.0	0.0	0.0	0.0
Max	207.0	177.5	150.0	247.0

Range for PUTS: 0 to 438 (max. based on highest toxicity level times maximum number of sprays recorded in baseline)
Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

We estimate our ANCOVA model with PUTS as the outcome (Table 6.12). This shows that cultivating FSB-resistant Bt Brinjal reduces the toxicity score by 7 points and this impact is statistically significant at 1 percent level. Relative to the baseline value for the control group, this represents a 29 percent reduction in the toxicity of pesticides applied to brinjal production.

Table 6.12 Impact of Bt brinjal cultivation PUTS

	(1)	**(2)**
Outcome	**PUTS**	**PUTS**
Treatment: Bt brinjal	-7.20***	-7.17***
	(1.57)	(1.57)
Controls		
Baseline outcome	Yes	Yes
Individual characteristics	No	Yes
Household characteristics	No	Yes
Observation	1,166	1,166

See notes in Table 8
Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

6.5 Summary

Bt Brinjal (BARI Bt Begun 4) was developed in order to resist the fruit and shoot borer (FSB) pest. In this section, we assess under field conditions, whether it is successful in doing so and whether, as a result, farmers reduce their use of pesticides. We find the following:

- Analysis of our primary outcome, the cost of applying pesticides per ha of brinjal cultivated, shows that farmers growing Bt brinjal spent Tk 7,175 less on pesticides per hectare, compared to control farmers (Table 6.6). This impact is statistically significant at the 1 percent level. This result is robust to the inclusion of controlling for selected baseline characteristics. When we consider alternative measures of pesticide use, we find that Bt brinjal farmers reduced the number of sprays by 7.3 and the quantity of pesticide sprayed by 4,617 gm (ml) per hectare. These impacts are statistically significant at the 1 percent level.
- Bt Brinjal reduces the toxicity of pesticide used by 7 percentage points on our scale and this impact is statistically significant at 1 percent level. Relative to the baseline value for the control group, this represents a 29 percent reduction in the toxicity of pesticides applied to brinjal production.
- Even with this reduction in pesticide use, farmers growing Bt brinjal report a large reduction in the extent of damage caused by fruit and shoot borer. The percentage of Bt brinjal farmers' plants affected by fruit and shoot borer fell from 34.9 percent at baseline to 1.8 percent at endline. By contrast, farmers growing the control crop (ISD-006) reported only a 2.1 percentage point reduction in damage caused by fruit and shoot borer between baseline and endline.

7. IMPACTS OF BT BRINJAL: BRINJAL PRODUCTION AND YIELDS

7.1 Introduction

As discussed earlier in this report, a prerequisite for the widespread adoption of Bt brinjal is evidence that it produces higher yields than conventional varieties. For this reason, in this section we assess the impact of Bt brinjal cultivation on brinjal yields, defined as kilogram (kg) produced per hectare of brinjal cultivated. As outlined in our pre-analysis plan, this is one of the study's primary outcomes. In addition, we also explore the mechanisms that underlie such differences. Do they arise because of differences in quantity harvested or area planted? We explore whether farmers growing brinjal retain more (or less) for home consumption, whether they give it to other households or use it as in-kind payment. Finally, we determine whether farmers growing Bt brinjal sell more or less of their harvest relative to control farmers. Having done so, we then explore whether these results differ by age, education or land operated.

The section is organized as follows. Section 7.2 describes the data available to us and provides some descriptive statistics. Section 7.3 provides our impact results on our primary outcome. Section 7.4 explores the mechanisms described above, and results from selected disaggregations. Section 7.5 concludes.

7.2 Data and Descriptive Statistics

Calculating yield requires information on both production and area cultivated. We begin by describing how these were measured.

At endline, farmers were asked to identify the months during which they harvested brinjal. For each month, they then indicated how much they had: harvested (including fruit that they harvested, but on inspection had to discard because of pest infestation or other disease); retained for home consumption; paid out to owners of leased plots; paid to hired labor; given away as a gift; discarded for any other reason, including damage due to pests or other diseases; and how much they had sold. All quantities were recorded in kilograms. While a few farmers indicated some harvesting in November and December 2017, the vast majority of harvesting took place between January and June 2018.[7]

[7] A similar method was used to collect baseline data. While this approach is consistent with what we described in our pre-analysis plan, it introduced an unexpected complication. For baseline, this recall period (November – June) captures both brinjal planted in October, but also brinjal planted earlier in the year. As a result, for some baseline farmers, their baseline data captures two harvests on the same plot of land, rather than one. This is seen, most notably, in the number of farmers reporting harvesting in November, December and January. At baseline, 494, 597 and 689 households respectively reported harvesting in these months. At endline (remembering that transplanting of seedlings took place largely in November), the number of farmers harvesting were 7, 29, and 340 in November, December and January, respectively.

As described in section 4, farmers agreed to grow brinjal in 10 decimal (0.10 acre) plots. At endline, we measured these plots using GPS.

Using these data, we calculate gross yields per hectare (quantity harvested in kilograms divided by area planted in hectares) and net yields per hectare (where net production is quantity harvested in kilograms minus fruit discarded for any other reason, including damage due to pests or other diseases). The net yield variable is the one defined as the primary outcome in our analysis plan.

Table 7.1 provides descriptive statistics on endline brinjal production by treatment status.

Table 7.1 Mean levels of endline brinjal production and yield, by treatment status

	Bt-brinjal	**ISD-006**	**Difference**
Quantity harvested kg	599.9	486.7	113.2
Quantity discarded kg	33.0	73.3	-40.3
Quantity paid out kg	38.1	31.9	6.2
Quantity retained for home consumption or seed stock kg	29.1	22.1	7.0
Quantity sold kg	499.7	359.4	140.3
Plot area ha	0.042	0.040	0.002
Gross yield kg per ha	14,700.3	12,456.1	2,244.2
Net yield kg per ha	13,914.3	10,483.1	3,431.2

Source: 2017 Baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Comparing the unconditional endline means, farmers growing Bt brinjal produced, on average, 113.2 kg more brinjal (600 kg v 487 kg for control farmers) over the period November 2017 – June 2018. Fewer (40 kg) brinjal were discarded by Bt brinjal farmers. Consequently, after accounting for amounts paid out and retained for home consumption or seed stock, Bt brinjal farmers were able to sell more brinjal. They did so on slightly smaller plot areas (remember, Bt brinjal farmers were supposed to plant a border around their fields). Gross and net yields per hectare were, on average, higher for Bt brinjal farmers.

While Table 7.1 suggests differences in mean values, we are also interested in the distribution of yields across Bt brinjal and control households. To assess these, we do the following. First, we calculate log net yields and plot their density functions for the two groups of households. Second, we test the null hypothesis that these distributions are equal.

Figure 7.1 Kernel density functions for net yields per ha, by treatment status

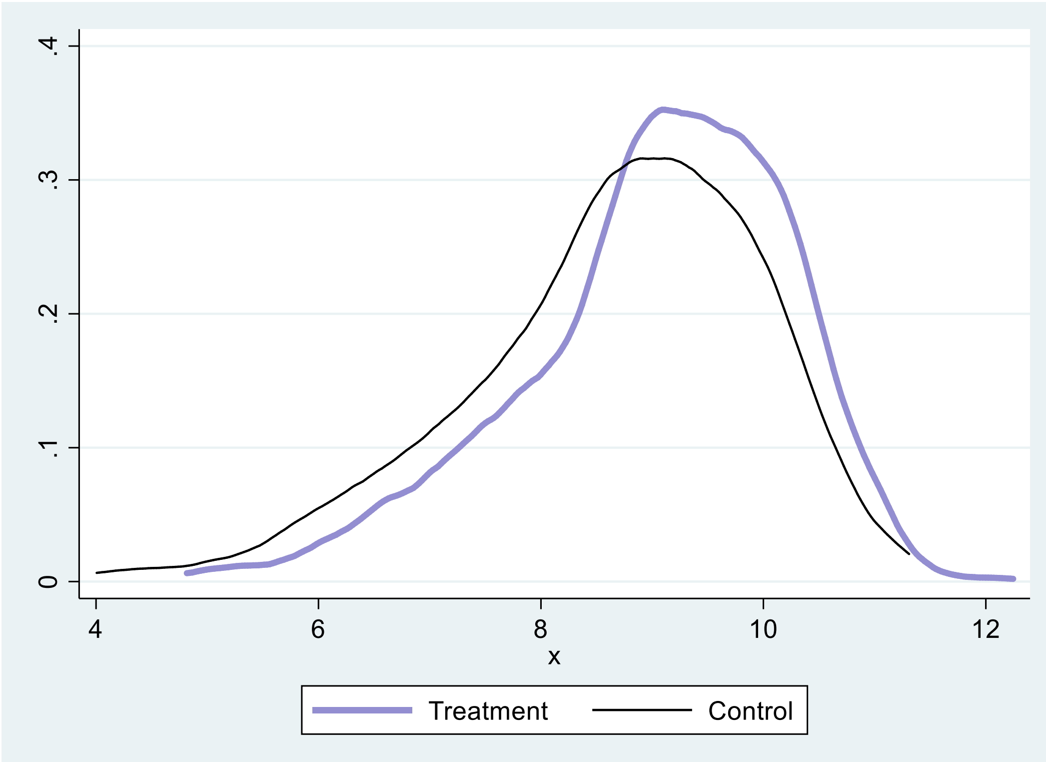

Figure 7.1 shows that, relative to control households, the distribution of (log) net Bt brinjal yields per hectare is shifted to the right. This suggests that mean differences between treatment and controls is not being driven by a small number of households but rather that Bt brinjal yields are generally higher than those from conventional varieties such as ISD-006. Using a Kolmogorov-Smirnov test, we can reject the null hypothesis that the two distributions are equal at the 1 percent level.

7.3 Basic Impact Results

We use an ANCOVA specification and the same household controls (years of education, age and years worked as a farmer of person with primary responsibility for brinjal production; wealth index and land operated (acres) at baseline) used in the previous section to assess impacts on outcomes. Standard errors account for clustering at the level of randomization, the village.

Table 7.2 Impact of Bt brinjal on yields

Outcome	(1) **Gross yield per ha**	(2) **Gross yield per ha**	(3) **Net yield per ha**	(4) **Net yield per ha**	(5) **Net yield per HA Winsorized**	(6) **Net yield per HA Winsorized**	(7) **Log Net yield per ha**	(8) **Log Net yield per ha**
Treatment: Bt brinjal	2,420.1*	2,355.6*	3,624.1***	3,622.1***	3,367.2***	3,372.9***	0.417***	0.420***
	(1,319.9)	(1,318.4)	(1,241.8)	(1,234.6)	(1,129.6)	(1,129.7)	(.117)	(.119)
Controls								
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Size of operated land in baseline	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,166	1,166	1,166	1,166	1,166	1,166	1,114	1,114

Source: 2017 Baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: Controls are age and education of household head; wealth; number of years working as a farmer and size of the operated land in baseline. Standard errors are clustered at village level. ** denotes significance at 5% level; *** denotes significance at 1% level.

Table 7.2 tells us that on a per hectare basis, net yields (one of our primary outcomes) are approximately 3,600 kg higher when farmers grow Bt brinjal. These results are robust to expressing the outcome variable as gross or net yields, including or excluding control variables apart from baseline values, winsorizing the data to account for outliers or expressing our dependent variable in logs. (All these specification tests were pre-specified in our pre-analysis plan.) The log results indicate that net yields are approximately 40 percent higher for Bt brinjal farmers.

During focus group discussions, most Bt brinjal farmers asserted that they achieved higher yields and higher fruit weight compared to conventional brinjal. Treatment farmers in Gobindaganj Upazila, Gaibandha District indicated that they each yielded between 40-55 *maunds* on their 10-decimal plots—that is, 1600-2,200 kg each, which is about 15-20 *maunds* (600-800 kgs) higher than previous yields from conventional brinjal. In Gaibanda Sadar Upazila, Gaibanda District, treatment farmers noted that local brinjal trees yield approximately 1 kg, whereas Bt brinjal yields are three-fold, with up to 3 kg per tree.

7.4 Mechanisms and Extensions

Table 7.3 explores the mechanisms underlying these results. Relative to the control farmers growing ISD-006, Bt brinjal farmers produced 113 kg more brinjal (column 2) per farmer. After harvesting, they discarded 42.92 kg less than control farmers (column 6). Bt brinjal farmers sold 146 kg more brinjal. All impacts are statistically significant at the 5 percent level.

We undertook a limited exploration of sample disaggregations, by median farmer age, education and total land holdings. Across these three disaggregations, we see no evidence of differential impact.

A recent socioeconomic study of Bt brinjal cultivation in Bangladesh shows that the yields of 4 different Bt brinjal varieties grown during winter of 2016-17 were 10 percent to 19 percent higher than non-Bt brinjal varieties (Rashid, Hasan, and Matin 2018).

7.5 Summary

In this section, we assess the impact of Bt brinjal cultivation on yields. Focusing on our primary outcome, net brinjal yields (defined as quantity harvested in kilograms minus fruit discarded for any other reason, including damage due to pests or other diseases all, divided by area cultivated in hectares), we find that Bt brinjal raises yields and that the magnitude of this impact is large—net yields are approximately 40 percent higher for Bt brinjal farmers. This result is robust to model specification, to measuring yields in gross or net terms and remains after we account for outliers. Our descriptive distributional work suggests that these yield gains are widespread. These differences in net yields are driven by two outcomes: quantity harvested is higher on Bt brinjal fields, by 113 kg per farmer; and after harvesting, fewer fruits were subsequently discarded because of damage due to other diseases, by 40 kg. Consequently, Bt brinjal farmers sold 143 kg more brinjal. These impacts are statistically significant at the 1 percent level. There are no statistically differences when we disaggregate by age, education or land operated.

Qualitative findings from treatment farmers and agriculture extension agents coincide with our impact results, noting higher yields and less wastage due to Bt brinjal cultivation.

Table 7.3 Impact of Bt brinjal on harvest, plot area, quantity discarded, paid out, retained for consumption and sold

Outcome	(1) **Harvest kg**	(2) **Harvest kg**	(3) **Area planted ha**	(4) **Area planted ha**	(5) **Qty discarded kg**	(6) **Qty discarded kg**	(7) **Qty paid out kg**	(8) **Qty paid out kg**	(9) **Qty retained for home consumption kg**	(10) **Qty retained for home consumption kg**	(11) **Qty sold kg**	(12) **Qty sold kg**
Treatment: Bt brinjal	117.7**	113.6 **	.002**	.002**	-40.54***	-42.92***	5.54	5.67	6.85***	6.46***	145.1***	143.8***
	(54.0)	(54.0)	(.001)	(.001)	(9.88)	(10. 36)	(4.91)	(4.94)	(2.19)	(2.09)	(49.3)	(49.3)
Controls												
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Size of operated land in baseline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166

Source: 2017 Baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: Controls are age and education of household head; wealth; number of years working as a farmer and size of the operated land in baseline. Standard errors are clustered at village level. ***, ** and * denote significance at 1%, 5% and 10% level.

8. IMPACTS OF BT BRINJAL: MARKETING, COSTS AND REVENUES

8.1 Introduction

In this study, we sought to develop an understanding of how marketing Bt brinjal compares with conventional varieties, whether Bt brinjal was sold at different prices, and the profitability of growing Bt brinjal.

This section is organized as follows: sub-section 8.2 reviews the data and descriptive statistics, followed by the basic impact results on cost of production and revenues, with a summary of the findings. We have incorporated qualitative findings, where relevant.

8.2 Marketing of Brinjal

This section explores the results of an analysis of the marketing practices of treatment and control farmers (Table 8.1).

8.2.1 Type of Buyer

Approximately two-thirds of brinjal farmers (65.4 percent of treatment and 61.5 percent control) sell their brinjal output to wholesalers.

About 13 percent of the farmers did not sell their brinjal, with slightly more control farmers not selling their output compared to treatment farmers.

From our analysis, we find the prevailing factor for farmers determining buyers is being paid a high or fair price (38.3 percent), followed by immediate payment (30.3 percent), and bulk purchases (19.6 percent).

Table 8.1 Marketing of brinjal at endline

	Treatment	Control	All
		(percent)	
Main buyer of brinjal			
Wholesaler	65.4	61.5	63.4
Retailer	10.9	10.6	10.8
Consumer	9.2	8.9	9.1
Village collector	2.4	4.7	3.5
Others	0.5	0.0	0.3
Did not sell	11.6	14.3	13.0
Major reason for the choice of buyer			
Pays high/fair price	39.7	36.7	38.3
Makes immediate payment	31.8	28.9	30.3
Buys in bulk	18.8	20.4	19.6
Buys limited quantity	5.5	8.1	6.8
Lives nearby	2.1	3.0	2.5
Makes advance payment	0.2	0.8	0.5
No other option	1.9	2.2	2.0
Location of sales			
District wholesale market	44.3	44.4	44.4
Local retail market	43.4	42.8	43.1
Farmer's field / own	10.5	10.6	10.5
Another district wholesale market	1.3	1.6	1.5
Other wholesale market	0.0	0.6	0.3
Others	0.6	0.0	0.3
Price agreed upon over phone	39.0	33.3	36.6
Means of transportation			
Tricycle	57.0	57.2	57.1
Motorized van	18.3	17.9	18.1
Headload	9.5	10.8	10.1
Bicycle	8.9	7.7	8.3
Motorbike	1.0	1.0	1.0
Rickshaw	0.2	0.6	0.4
Push cart	0.2	0.0	0.1
Truck/pickup	0.0	0.6	0.3
Others	0.6	0.0	0.3
Sold at home	4.4	4.3	4.4

Source: 2017 endline survey for Bt Brinjal Impact Evaluation, IFPRI.

8.2.2 Location of Sale

About 44 percent of all study farmers sell their brinjal output at the district wholesale market, while the local retail market emerges as a secondary preference at 43.1 percent. As the sale locations are consistent between treatment and control farmers, these findings suggest that treatment farmers were not compelled to change where they sell their output based on selling a new variety.

8.3 Cost of Production

The study collected plot-level data on the input costs for treatment and control farmers. The average prices are multiplied by respective input coefficients to calculate per-hectare costs of these inputs. Costs of irrigation, seedling raising, pesticide use, and mechanical power per plot are obtained directly from the survey and converted into per-hectare costs.

Most farmers in Bangladesh rely heavily on family labor for crop cultivation. If family members cannot find jobs, or if family labor will not be offered to the market when the crop in question is not produced, then the opportunity cost of family labor is likely to be much lower than prevailing labor wage rates. However, when labor must be hired to supplement family labor, the use of a market wage rate to value family labor may be appropriate (Ahmed 1994). Although the surveys for this study collected information on the use of both hired and family labor, we use only the cost of hired labor in our analysis as the opportunity cost of family labor is not known. Hired labor coefficients for different activities are multiplied by respective wages for these activities to obtain labor costs.

Table 8.2 Input costs per hectare for Bt Brinjal and ISD-006 cultivation at endline

Cost	Treatment	Control
	(taka per hectare)	
Seed/seedling	5,461	5,539
Fertilizer	30,326	32,026
Irrigation	11,241	11,867
Pesticide	14,852	22,145
Machinery	7,600	8,097
Total hired labor	2,505	2,227
Total cash cost	72,109	81,902

Source: 2017 Baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Table 8.2 features a breakdown of costs of inputs per hectare for treatment farmers cultivating Bt brinjal and control farmers growing conventional brinjal. The total costs of production for Bt brinjal per hectare are lower than local brinjal at endline (Tk 72,109 for treatment vs. Tk. 81,902 for control farmers) mainly because Bt brinjal farmers incurred a considerably less cost on pesticides compared to control farmers.

The qualitative research validated the quantitative findings on input costs. For example, one SAAO in Pirgacha Upazila, Rangpur District indicated that Bt brinjal required less pesticide:

In brinjal cultivation, the main cost is pesticides, but in Bt brinjal cultivation, there was less pesticide required than the regular varieties. Spraying once in a week was enough for Bt, whereas other varieties required as often as three times a week. This is a financial savings for farmers.

Another SAAO in Gaibandha Sadar Upazila, Gaibandha District attempted to quantify farmers' savings from lower pesticide use due to Bt brinjal's resistance to fruit and shoot borer:

Normal brinjal requires spraying [pesticide] every 5 days for majra poka (fruit and shoot borer), but since Bt brinjal deters majra poka, no spraying is required for that pest each month. One time's spraying costs about Tk 300, amounting to Tk 1,200 each month if farmers need to spray four times.

8.4 Impact Results

Again, we employ an ANCOVA specification for estimating impacts and control for age, years of education, wealth, number of years working as a farmer, and the size of operated land at baseline. Standard errors account for clustering at the village level.

Table 8.3 provides the impact of Bt brinjal on cost. Bt brinjal cost of production per hectare was Tk 9,261 lower compared to local brinjal (column 1). When we winsorize the data to reduce outlier bias, we find that the cost of Bt brinjal production is Tk 8,215 lower per hectare compared to local brinjal production (column 3). Overall, the cost of Bt brinjal production per hectare dropped by about 11 percent (column 6) and cost per kg by 30 percent (column 10), which are statistically significant at the 1 percent level.

Table 8.4 shows the impact of Bt brinjal on the cost of pesticide use (including costs of pesticides and hired labor cost for pesticide application), with identical household and individual controls applied. Treatment farmers' cost of pesticide per hectare reduced by Tk 6,715 (column 2), translating to a 40 percent reduced cost compared to control farmers (column 4). The cost of pesticide per kg for treatment farmers growing Bt brinjal was 60 percent less than control farmers (column 8). Results across the board are statistically significant at the 1 percent level.

Table 8.5 describes the impact of Bt brinjal cultivation on sales revenue. We are cobbling together an encouraging portrait of the profitability of Bt brinjal: in addition to reducing overall production costs, namely driven by reduced pesticide costs, we see that Bt brinjal increased sales revenue by Tk 1,962, controlling for household and individual characteristics (column 2). This increased value translates to a 55 percent increase (column 4). All results presented are statistically significant at the 1 percent level.

Table 8.3 Impact of Bt brinjal on cost

Outcome	(1) Cost per HA	(2) Cost per HA	(3) Cost per HA Winsorized	(4) Cost per HA Winsorized	(5) Log cost per HA	(6) Log cost per HA	(7) Cost per kg	(8) Cost per kg	(9) Log Cost per kg	(10) Log Cost per kg
Treatment: Bt brinjal	-9,260.5***	-9,260.4***	-8,214.6***	-8,265.5***	-0.105***	-0.105***	-8.17 **	-8.31 **	-0.309***	-0.310***
	(2131.8)	(2129.5)	(1995.0)	(1996.8)	(.028)	(.028)	(4.04)	(4.06)	(0.102)	(0.103)
Controls										
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Size of operated land in baseline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,174	1,174	1,174	1,174	1,174	1,174	1,122	1,122	1,122	1,122

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Notes: Controls are age and education of household head; wealth; number of years working as a farmer and size of the operated land in baseline. Standard errors are clustered at village level. ** denotes significance at 5% level; *** denotes significance at 1% level.

Table 8.4 Impact of Bt brinjal on cost of pesticide use

Outcome	(1) **Cost of pesticide HA**	(2) **Cost of pesticide HA**	(3) **Log Cost of pesticide HA**	(4) **Log Cost of pesticide HA**	(5) **Cost of pesticide Per kg**	(6) **Cost of pesticide Per kg**	(7) **Log Cost of pesticide Per kg**	(8) **Log Cost of pesticide Per kg**
Treatment: Bt brinjal	-6,652.2***	-6,714.7***	-0.418***	-0.423***	-3.53***	-3.57***	-0.615***	-0.618***
	(1,120.3)	(1,118.6)	(.057)	(.057)	(1.01)	(1.03)	(.109)	(.110)
Controls								
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Size of operated land in baseline	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,174	1,174	1,147	1,147	1,122	1,122	1,102	1,102

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

Notes: Controls are age and education of household head; wealth; number of years working as a farmer and size of the operated land in baseline. Standard errors are clustered at village level. *** denotes significance at 1% and 5% level.

Table 8.5 Impact of Bt brinjal on revenue

Outcome	(1) Value of sales Taka	(2) Value of sales Taka	(3) Log Value of sales Taka	(4) Log Value of sales Taka
Treatment: Bt brinjal	1,963.7***	1,962.2***	0.565***	0.548***
	(475.7)	(465.7)	(0.115)	(0.116)
Controls				
Baseline outcome	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes
Size of operated land in baseline	No	Yes	No	Yes
Observations	1,166	1,166	980	980

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: Controls are age and education of household head; wealth; number of years working as a farmer and size of the operated land in baseline. Standard errors are clustered at village level. *** denotes significance at 1% level.

Table 8.6 provides the impact of Bt brinjal on price for those who sold in the market. The unit price (Tk per kg) increased by 10 percent as a result of selling Bt brinjal (column 4).

Through our qualitative research component, we sought to glean deeper insights on treatment farmers' experiences in marketing Bt brinjal, specifically related to how Bt brinjal compared to conventional brinjal in terms of market demand and selling price.

One market trader spoke about his experience managing low consumer demand for Bt brinjal:

> *At the beginning, I could not sell this brinjal in this market; I forced them to take it, especially those who are known to me to come every day. I told them no problem if you do not pay money. Then, when they took the brinjal home and ate it, they told me to give them more brinjal. Since then, demand is getting higher. In fact, it was not sold for two or three days at the beginning. After that, I enticed all of them to buy this. Since then, I did not have any problems.*

Next, we look at impact of Bt brinjal on profit (Table 8.7). Treatment farmers increased profits by Tk 38,063 per hectare (column 2). When we winsorize the data to account for any potential outliers, we find that profits per hectare increased by Tk 33,827 (column 4). Similarly, profits per kg jump to Tk 9.10 (column 6), controlling for individual and household characteristics and size of operated land at baseline.

Table 8.6 Impact of Bt brinjal on price for those who sold

Outcome	(1) Unit price Taka per kg	(2) Unit price Taka per kg	(3) Log Unit price Taka per kg	(4) Log Unit price Taka per kg
Treatment: Bt brinjal	1.01**	0.963**	0.148***	0.143***
	(0.418)	(0.416)	(0.053)	(0.053)
Controls				
Baseline outcome	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes
Size of operated land in baseline	No	Yes	No	Yes
Observations	980	980	980	980

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: Controls are age and education of household head; wealth; number of years working as a farmer and size of the operated land in baseline. Standard errors are clustered at village level. *** and ** denote significance at 1% and 5% level.

Table 8.7 Impact of Bt brinjal on profit

Outcome	(1) Profit per HA	(2) Profit per HA	(3) Profit per HA Winsorized	(4) Profit per HA Winsorized	(5) Profit per kg	(6) Profit per kg
Treatment: Bt brinjal	38,967.6***	38,063.4***	34,359.0***	33,827.0***	9.00**	9.11 **
	(10,806.5)	(10,815.0)	(9,156.3)	(9,216.9)	(4.04)	(4.06)
Controls						
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes
Size of operated land in baseline	No	Yes	No	Yes	No	Yes
Observations	1,174	1,174	1,174	1,174	1,122	1,122

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: Controls are age and education of household head; wealth; number of years working as a farmer and size of the operated land in baseline. Standard errors are clustered at village level. ** denotes significance at 5% level; *** denotes significance at 1% level.

8.5 Summary

Broadly, this section examined the changes in costs of production and revenues as a result of cultivating Bt brinjal. Overall, our results are mutually supportive—cost of production drops, particularly driven down by reduced pesticide costs; and revenues increase, mainly because higher yields of Bt brinjal and higher price.

Bt brinjal cultivation increases gross revenues from brinjal production (total production *x* price received) by 55 percent, resulting in an increase in values by Tk 1,962 per hectare. The lower cost of production and higher gross revenues result in substantial increase in profits from cultivating Bt brinjal for treatment farmers compared conventional brinjal produced by control farmers.

9. IMPACTS OF BT BRINJAL: HEALTH

9.1 Introduction

As discussed in Section 6, Bt brinjal reduces the use of pesticides, including those which are particularly hazardous to human health. In this section, we assess a potential consequence of this reduced use, reductions in the reporting of symptoms and illness consistent with pesticide poisoning. Specifically, consistent with our pre-analysis plan, we assess the following:

- Does the cultivation of Bt brinjal reduce household self-reports of symptoms consistent with pesticide poisoning? How large is this change?
- Does the cultivation of Bt brinjal reduce the number of days that household members are too ill to work? How large is this change?
- Does the cultivation of Bt brinjal change healthcare and expenditures related to health care? How large is this change?

For these outcomes, we also specified that we would assess whether these impacts differed by age, sex, and relationship to the household head.

The section is organized as follows. Section 9.2 describes the data available to us and provides some descriptive statistics. Section 9.3 provides our impact results. Section 9.4 considers an alternative explanation for our findings, namely differences pesticide handling practices. Section 9.5 concludes.

9.2 Data and Descriptive Statistics

In both the baseline and endline surveys, for those individuals in the household who reported undertaking work on any field crops, we asked if during the last agricultural season (November to June) if they had experienced: eye irritation; headaches; dizziness; nausea or vomiting diarrhea; fever; convulsion; shortness of breath, wheezing or coughing; skin disease, joint pain (stiffness, swelling). We also asked how long (in days) these symptoms persisted, the number of days during the agricultural season that these symptoms prevented the individual from working, and cash medical expenses associated with treating these symptoms.

Table 9.1 shows that at baseline, the average age was 40. Somewhat more than half, 62 percent are male and 38 percent are female. About a third of the sample (31 percent) is the spouse of the head with 18 percent being a child, son or daughter-in-law or grandchild of the head, five percent are other relatives of the head and the remainder (46 percent) household heads. Most (69 percent) report at least one symptom consistent with pesticide poisoning and, on average, respondents report experiencing 1.8 such symptoms. A third (34 percent) report that they missed a day's work because of these symptoms; days missed averaged 1.8 days. Just under half (42 percent) reported that they sought medical attention to address these symptoms and 58 percent stated that they had incurred cash expenses to deal with these. On average, individuals spent Tk 675 on fees, tests, transport, and medicines when treating these symptoms. Note that the variation in these expenses (standard deviation is 3457) is high relative to the mean.

Table 9.1 Descriptive statistics for analysis of self-reported health status, baseline

	Mean	Standard Deviation
Age	40.8	14.2
Female	0.38	0.49
Spouse of head	0.31	0.46
Child, son/daughter-in-law or grandchild of head	0.18	0.39
Other relation	0.05	0.22
Any symptom consistent with pesticide poisoning	0.69	0.46
Number of symptoms	1.85	1.78
Any work days lost because of symptoms	0.34	0.47
Number of days lost because of symptoms	1.89	4.53
Sought treatment for symptoms	0.42	0.49
Incurred expenses to address symptoms	0.58	0.49
Medical expenses incurred to address symptoms (Taka)	675	3,457

Source: 2017 baseline survey for Bt Brinjal Impact Evaluation, IFPRI.
Notes: Sample size is 2,531.

9.3 Results

We use an ANCOVA specification and the same household controls (years of education, age and years worked as a farmer of person with primary responsibility for brinjal production; wealth index and land operated (acres) at baseline) used in previous sections to assess outcomes in other domains. Because illness is reported at an individual level, we also control for individual characteristics (age, sex, relationship to household head). As self-reported illness data are only available for individuals who engaged in crop cultivation, we restrict our sample to the 2,531 individuals who did so at both baseline and endline. We use linear probability models when the outcome is dichotomous, tobit and poisson estimators for count outcomes and tobit estimators when the outcome is continuous but censored at zero. Standard errors account for clustering at the level of randomization, the village.

Table 9.2 tells us that individuals engaged in crop cultivation that includes Bt brinjal were 6.2-7.5 percentage points less likely to report symptoms consistent with pesticide poisoning (Table 9.2, columns 1 and 2). There is some evidence that cultivation of Bt brinjal reduces the number of symptoms reported though this impact is sensitive to model specification and the estimator chosen. Individuals in households growing Bt brinjal were 6.5-7.7 percentage points less likely to report that they needed to seek medical care for these symptoms (Table 9.3). While the coefficient on Bt brinjal cultivation is negative for the number of days lost because of these symptoms and the level of medical expenses associated with treating these symptoms, these coefficients are not statistically significant (Table 9.3).

We run three checks on model specification: (1) For our core results, the reduction in reported symptoms and the seeking of medical care, we re-estimate using a probit and calculate marginal effects. This produces almost exactly the same results as those generated by the linear probability model; (2) We winsorize the number of days lost because of these symptoms and the cash costs associated with treatment. Re-estimating with the winsorized data does not produce statistically significant impacts; and (3) For days lost and cash costs, we run Powell's (1984) censored least absolute deviations estimator (CLAD); this does not produce statistically significant impacts either.

Table 9.2 Impact of Bt brinjal cultivation on self-report of symptoms consistent with pesticide poisoning

Outcome	(1) **Any symptom of pesticide poisoning**	(2) **Any symptom of pesticide poisoning**	(3) **# symptoms of pesticide poisoning**	(4) **# symptoms of pesticide poisoning**	(5) **# symptoms of pesticide poisoning**	(6) **# symptoms of pesticide poisoning**
Estimator	LPM	LPM	Tobit	Tobit	Poisson	Poisson
Treatment: Bt brinjal	-0.075** (0.032)	-0.062** (0.032)	-0.304** (0.149)	-0.268* (0.148)	-0.117* (0.068)	-0.103 (0.068)
Controls						
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes
Observations	2,531	2,531	2,531	2,531	2,531	2,531

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: Individual characteristics are age, sex and relationship to household head. Household characteristics include characteristics of the individual responsible for brinjal production (age, education, years working as a farmer), land operated by the household and household wealth index derived from principal components (using number of rooms in the dwelling; whether the dwelling has electricity; physical states of the dwelling and ownership of the following consumer durables: wrist watch, color tv, bicycle, tri van, motorcycle and solar panels). Standard errors clustered at the village level. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table 9.3 Impact of Bt brinjal cultivation on consequences of symptoms consistent with pesticide poisoning

Outcome	(1) **Symptoms prevented person from working**	(2) **Symptoms prevented person from working**	(3) **Sought medical treatment for any of these symptoms?**	(4) **Sought medical treatment for any of these symptoms?**	(5) **Incurred cash expenses associated with treating symptoms?**	(6) **Incurred cash expenses associated with treating symptoms?**	(7) **Cash expenses associated with treating symptoms**	(8) **Cash expenses associated with treating symptoms**
Estimator	LPM	LPM	LPM	LPM	LPM	LPM	Tobit	Tobit
Treatment: Bt brinjal	-0.034	-0.024	-0.077**	-0.065*	-0.061*	-0.048	-220.8	-172.7
	(0.026)	(0.025)	(0.035)	(0.034)	(0.032)	(0.031)	(224.6)	(219.6)
Controls								
Baseline outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2,531	2,531	2,531	2,531	2,531	2,531	2,531	2,531

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: See Table 9.2.

Table 9.4 disaggregates our key findings by sex; there is no statistically significant difference in impacts between men and women but with smaller sample sizes, there is a slight loss of precision. Disaggregating other outcomes by sex does not reveal any other impacts of Bt brinjal cultivation. We also estimated these impact models disaggregating by age and, separately, by relationship to household head. These disaggregations show similar coefficients across different groups but again, with smaller sample sizes and in some instances, loss of precision.

Many individuals in our sample have worked as farmers for decades, have been exposed to pesticides for a very long period of time and consequently, may have developed chronic conditions consistent with pesticide poisoning. We wondered if the presence of pre-existing chronic conditions might affect our results. To assess this, we did the following. At baseline, approximately 20 percent of our sample (522/2,531) reported suffering from either persistent respiratory problems or from persistent skin disease. We disaggregated our sample, putting all such individuals into one group and everyone else (those not suffering from these chronic conditions) into a second group.

Table 9.4 Selected impacts on self-reported health outcomes, by sex

Outcome	(1) **Any symptom of pesticide poisoning**	(2) **Any symptom of pesticide poisoning**	(3) **Sought medical treatment for any of these symptoms?**	(4) **Sought medical treatment for any of these symptoms?**
	Women	**Men**	**Women**	**Men**
Estimator	LPM	LPM	LPM	LPM
Treatment: Bt brinjal	-0.072*	-0.058*	-0.083**	-0.051
	(0.038)	(0.033)	(0.040)	(0.036)
Controls				
Baseline outcome	Yes	Yes	Yes	Yes
Individual characteristics	No	Yes	No	Yes
Household characteristics	No	Yes	No	Yes
Observations	970	1,561	970	1,561

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: See Table 9.2.

Results are reported in Table 9.5 for four outcomes. Individuals who had a pre-existing chronic condition consistent with pesticide poisoning and who lived in villages randomly selected to grow Bt brinjal were 11 percentage points less likely to report a symptom of pesticide poisoning, reported 0.2 fewer such symptoms, were 12 percentage points less likely to see medical care for these symptoms, and were 11 percentage points less likely to incur cash medical expenses to treat these symptoms. All impacts are statistically significant at the 5 percent level.[8] For each of these outcomes, while the impact of Bt brinjal cultivation is larger for individuals with pre-existing chronic conditions than it is for individuals without these conditions, we come close but do not reject the null hypothesis that these impacts are equal across the two groups.

[8] There were no statistically significant impacts for either group for symptoms prevented person from working and level of cash expenses associated with treating symptoms.

Table 9.5 Selected impacts on self-reported health outcomes, by chronic disease status

Outcome	(1) Any symptom of pesticide poisoning	(2) Any symptom of pesticide poisoning	(3) # symptoms of pesticide poisoning	(4) # symptoms of pesticide poisoning	(5) Sought medical treatment for any of these symptoms?	(6) Sought medical treatment for any of these symptoms?	(7) Incurred cash expenses associated with treating symptoms?	(8) Incurred cash expenses associated with treating symptoms?
	Chronic respiratory or skin disease	No chronic respiratory or skin disease	Chronic respiratory or skin disease	No chronic respiratory or skin disease	Chronic respiratory or skin disease	No chronic respiratory or skin disease	Chronic respiratory or skin disease	No chronic respiratory or skin disease
Estimator	LPM	LPM	Poisson	Poisson	LPM	LPM	LPM	LPM
Treatment: Bt brinjal	-0.115***	-0.050**	-0.215**	-0.068	-0.122**	-0.050	-0.109**	-0.033
	(0.038)	(0.021)	(0.093)	(0.073)	(0.050)	(0.036)	(0.044)	(0.034)
P value on equality of coefficients	0.14		0.10*		0.15		0.10*	
Observations	522	2,012	522	2,012	522	2,012	522	2,012

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.
Notes: See Table 9.2.

Table 9.6 Pesticide handling practices by treatment group and survey round

	Baseline		Endline	
	Treatment	**Control**	**Treatment**	**Control**
	Do you read the labels on pesticide bottles/packs?			
Yes	62.8%	62.2%	69.0%	68.3%
Cannot read, have some else read it	8.8	12.4	19.7	20.9
No	23.1	21.0	10.8	9.2
Cannot read, do not have someone else read it	5.3	4.4	0.5	1.5
	Do you follow the instructions on the label?			
Yes	36.8	38.5	67.3	67.7
Yes, sometimes	34.1	34.8	21.8	22.9
No	5.9	5.8	0.2	0.2
No, do not read label	23.1	21.0	10.8	9.3
	How do you prepare pesticide?			
With bare hands	71.1	74.2	59.9	61.7
Wearing gloves	11.4	9.3	7.1	11.1
With a stick (but bare hands)	85.1	80.7	81.8	83.5
With a stick wearing gloves	12.7	9.5	9.1	14.1
	Spraying practices			
Wears long sleeves	92.5	93.2	95.8	97.1
Wears long trousers	91.7	92.7	96.0	97.1
Shields face	67.9	63.7	67.8	69.2
Covers head	58.5	54.0	61.2	68.8
Wears eye protection	13.7	12.2	8.9	10.6
Wears gloves	12.2	8.0	8.8	11.2
Wears sandal/shoes	11.5	10.0	16.2	19.9
	Do you determine the wind direction before spraying?			
Yes	89.5	89.5	95.8	97.5
	Do you spray when it is windy?			
Yes	5.4	7.3	4.7	4.9
	After applying pesticides			
Wash hands after spraying	97.5	98.1	96.3	97.1
Wash face after spraying	96.6	96.7	95.6	97.1
Take bath/shower after spraying	95.1	96.4	96.1	97.3
Change clothes after spraying	96.1	97.4	95.8	97.6

Source: 2017 baseline and endline surveys for Bt Brinjal Impact Evaluation, IFPRI.

9.4 Pesticide handling

Both treatment and control households received training on the safe handling of pesticides. If treatment households were more likely to adopt these practices, then the differences in self-reported illness could reflect this training, not the cultivation of Bt brinjal.

To assess this possibility, at baseline and endline, we asked farmers cultivating brinjal to describe how they handled pesticides. Results are reported in Table 9.6. The following patterns emerge:

- There are some correct practices that the vast majority of farmers, irrespective of treatment status, undertook at both baseline and endline. These include: washing after spraying; changing clothes; wearing long sleeved clothing; and wearing trousers.
- There were some practices that more farmers undertook at endline compared to baseline. These included: reading and following instructions; not using bare hands when mixing pesticides; and checking for wind direction before spraying. These improvements were observed in both treatment and control households.
- There were some practices that few farmers undertook at baseline and where there was little change at endline. These included: mixing pesticides with a stick and wearing gloves; and wearing eye protection, gloves or sandals/shoes while spraying. We see little evidence of change in either treatment or control households.

Crucially, looking across these practices, we see that they are similar across treatment and control households at baseline. Where we observe changes, we observe them for both groups. This suggests that differences in handling pesticide practices does not account for the reduction in the self-reported symptoms described above.

9.5 Summary

We assess a potential consequence of the reduction in pesticide use shown in section 6; reductions in the reporting of symptoms and illness consistent with pesticide poisoning. At baseline, such symptoms were common. Most brinjal farmers (69 percent) reported at least one symptom consistent with pesticide poisoning and, on average, respondents report experiencing 1.8 such symptoms. Just under half (42 percent) reported that they sought medical attention to address these symptoms and 58 percent stated that they had incurred cash expenses to deal with these.

Individuals growing Bt brinjal were 6.2-7.5 percentage points less likely to report symptoms consistent with pesticide poisoning. There is some evidence that cultivation of Bt brinjal reduces the number of symptoms reported though this impact is sensitive to model specification and the estimator chosen. Individuals in households growing Bt brinjal were 6.5-7.7 percentage points less likely to report that they needed to seek medical care for these symptoms (Table 9.3). While Bt brinjal cultivation reduces the number of days lost because of these symptoms and the level of medical expenses associated with treating these symptoms, these estimates are not statistically significant. Impacts are robust to model specification and estimation. They do not differ by sex or age. Individuals who had a pre-existing chronic condition consistent with pesticide poisoning and who lived in villages randomly selected to grow Bt brinjal were 11 percentage points less likely to report a symptom of pesticide poisoning, reported 0.2 fewer such symptoms, were 12 percentage points less likely to seek medical care for these symptoms and were 11 percentage points less likely to incur cash medical expenses to treat these symptoms. All impacts are statistically significant at the 5 percent level. For each of these outcomes, while the impact of Bt brinjal cultivation is larger for individuals with pre-existing chronic conditions than it is for individuals without these conditions, we come close but do not reject the null hypothesis that these impacts are equal across the two groups.

10. CONCLUSIONS

[To be completed]

REFERENCES

Ahmed, A. U., 1994. *Input-output coefficients for estimating rice production costs and returns in Bangladesh.* Bangladesh Food Policy Project Manuscript 61. Washington, D.C.: International Food Policy Research Institute.

Ahmed, A.U. 2013. Bangladesh Integrated Household Survey (BIHS) 2011-2012. Washington, D.C.: International Food Policy Research Institute (datasets). http://hdl.handle.net/1902.1/21266

Ahmed, A.U. and Tauseef, Salauddin. 2018. *Climbing up the ladder and watching out for the fall: Poverty dynamics in rural Bangladesh*. IFPRI Discussion Paper 1791. Washington, DC: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/singleitem/collection/p15738coll2/id/133034

Bruhn, M. and McKenzie, D. 2009. In pursuit of balance: Randomization in practice in development field experiments. *American Economic Journal: Applied Economics*, 1(4), 200-232.

Department of Agricultural Extension of Ministry of Agriculture (DAE), Government of Bangladesh, 2016. List of registered agricultural biopesticides and public health pesticides in Bangladesh approved up to 65th technical advisory committee meeting. http://www.dae.gov.bd

Fitzgerald, J.M., Gottschalk, P. and Moffitt, R.A. 1998a. 'An analysis of sample attrition in panel data', *Journal of Human Resources*, vol. 33(2), pp. 251–99.

________. 1998b. 'The impact of attrition in the PSID on intergenerational analysis', *Journal of Human Resources*, 33(2), pp. 300–44.

McKenzie, D. 2012. Beyond baseline and follow-up: The case for more T in experiments. *Journal of Development Economics*, 99(2), 210-221.

________. 2015. Tools of the Trade: a joint test of orthogonality when testing for balance. Development Impact Blog. Available at: https://blogs.worldbank.org/impactevaluations/tools-trade-joint-test-orthogonality-when-testing-balance.

Powell, J. L. 1984. Least absolute deviations estimation for the censored regression model. *Journal of Econometrics*, 25(3), 303-325.

Rashid, M. A., Hasan, M. K., and Matin, M.A. 2018. Socio-economic performance of Bt eggplant cultivation in Bangladesh. *Bangladesh Journal of Agricultural Research*, 43(2), 187-203.

United Nations. 2011. Globally Harmonized System of Classification and Labelling of Chemicals (GHS). New York: United Nations.

World Health Organization, 2010. The WHO recommended classification of pesticides by hazard and guidelines to classification 2009-10. Geneva: World Health Organization.