A Seminar Paper on

Ecological Compatibility of Genetically Modified Crops and Pest Managements in Bangladesh

Course Code: ENT 598
Term: Winter, 2022

Submitted to

Course Instructors	Major Professor
1. Dr. A. K. M. Aminul Islam Professor 2. Dr. Satya Ranjan Saha Professor 3. Dr. Shaikh Shamim Hasan Professor 4. Dr. Dinesh Chandra Saha Associate Professor	Dr. Md. Ruhul Amin Professor Department of Entomology BSMRAU, Gazipur

Submitted by

ANIK SAHA

MS Student

Reg. No.: 17-05-4239

Department of Entomology

Bangabandhu Sheikh Mujibur Rahman Agricultural University
Gazipur 1706

Ecological Compatibility of Genetically Modified Crops and Pest Managements in Bangladesh[1]

Anik Saha[2]

ABSTRACT

Genetically modified (GM) crops have become increasingly common in the global food supply, with the potential to improve agricultural productivity and food security. In Bangladesh, the only approved GM crop is Bt-brinjal, which was developed to combat the brinjal shoot and fruit borer. However, the ecological compatibility and potential risks of GM crops have been a subject of much debate and controversy in Bangladesh. This review paper analyzes the compatibility of GM crops with pest management practices in Bangladesh, explores their ecological impacts, and compares them with conventional crops. The study finds that Bt-brinjal reduces the infestation of fruit by both number and size, leading to significant reductions in insecticide usage and cost. There are no significant adverse impacts on non-target organisms or soil organisms, and no evidence of unwanted outcrossing, horizontal gene transfer, or weediness. In comparison with conventional brinjal varieties, Bt-brinjal shows lower production costs, higher net returns, and higher market prices. The findings suggest that Bt-brinjal has the potential to contribute to sustainable agricultural development in Bangladesh, but further research and monitoring are needed to fully understand the ecological implications of GM crop cultivation.

Key words: Bt-brinjal, non-target species Environmental risks, Sustainable agriculture and Genetic engineering

---

[1] A Paper for the Seminar Course ENT 598; Winter, 2022

[2] MS Student, Department of Entomology, BSMRAU, Salna, Gazipur 1706.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Genetically modified crops have become a common topic of discussion and are increasingly present in our food supply. Genetically modified crops can be defined as plants in which the genetic material (DNA) has been modified in a way that does not occur naturally by mating or natural recombination. The technology is often called "genetic engineering". It allows selected individual genes to be transferred from one organism into another, also between nonrelated species (World Health Organization, 2017). The genetic modifications are intended to provide benefits such as increased resistance to pests and diseases, improved tolerance to environmental stresses such as drought or temperature extremes, and enhanced nutritional content. In recent years, the development and adoption of genetically modified (GM) crops for pest management have gained significant attention as potential solutions to increase agricultural productivity and ensure food security (Sharma et al., 2022). However, the ecological compatibility of these practices has been a topic of much debate and controversy, particularly in developing countries such as Bangladesh (Mahmuda et al., 2022). Concerns have been raised about the potential environmental risks associated with these practices, such as the development of pest resistance, the impact on non-target species, and the potential for gene flow to wild populations. Effects of GM crops may extend beyond their target pests to include non-target species, which often provide ecological and pest management services (Lundgren et al., 2009). With a growing population and limited resources, Bangladesh is heavily reliant on agriculture as a means of economic growth and food security (Yu et al., 2010). As a result, understanding the ecological impact of GM crops and adopting its cultivation is critical for sustainable agricultural development in the region. In Bangladesh, there is only one approved GM crop- Bt-brinjal, which was approved in 2013. Bt-brinjal can be used as resistant cultivars against serious pest of brinjal, brinjal shoot and fruit borer (BSFB) to replace or reduce the chemical pesticide application of pest managements (Shelton et al., 2019). Some other GM crops such as, goden rice, Bt- cotton and blight resistant potato is in line and ready to be approved (Ahmad, 2017; Stokstad, 2019; ISAAA, 2022). Given these concerns, it is critical to assess the ecological compatibility of GM crops and pest management practices in Bangladesh, particularly in the context of the region's unique environmental, social, and economic conditions.

Based on the circumstances described above, this review paper has been created with the aim of fulfilling the following objectives:

1. To analyse the compatibility of genetically modified crops over pest management practices in Bangladesh.
2. To explore the ecological impacts of genetically modified crops in Bangladesh.
3. To compare the performance of genetically modified crops with conventional crops.

CHAPTER II

MATERIALS AND METHODS

The purpose of this seminar paper is to provide a review on ecological compatibility of genetically modified crops and pest managements in Bangladesh. All information presented here was obtained from secondary sources. The sources used included books, journals, reports, internet searches, and resources from the Bangabandhu Sheikh Mujibur Rahman Agricultural University library. I also received sufficient guidance from my major professor and course instructors, which proved helpful in completing my seminar report. To acquire knowledge, I conducted searches on similar websites on the internet. The collected information was then compiled to create this seminar paper, which drew from a variety of publications, journals, and websites.

CHAPTER III

REVIEW OF MAJOR FINDINGS

3.1 World scenario of genetically modified (GM) crops:

The introduction of commercial genetically modified (GM) crops took place in 1996. In the 24th year of commercialization of GM crops in 2019, 29 countries grew 190.4 million hectares of GM crops. The global area of GM crops has increased ~112-fold from 1.7 million hectares in 1996 to 190.4 million hectares in 2019- this makes GM crops the fastest adopted crop technology in recent times. An accumulated 2.7 billion hectares were achieved in 24 years (1996-2019) of GM crop commercialization. The USA led the GM crop planting in 2019 at 71.5 million hectares, followed by Brazil (52.8 million hectares), Argentina (24 million hectares), Canada (12.5 million hectares), and India (11.9 million hectares) (Table 1) for a total of 172.7 million hectares, representing 91% of the global area. Thus, GM crops benefited more than 1.95 billion people in the 5 countries or 26% of the current world population of 7.6 billion (ISAAA, 2019). The majority of these biotech crops were designed to be pest-resistant or herbicide-resistant, which has led to increased agricultural productivity and farmers' income. This shows that the impact of biotech crops has been proven over time, and the technology has continued to develop gradually (Cho et al., 2020).

Table 1: Global area of biotech crops in 2019 (ISAAA, 2019)

Rank	Country	Area (million hectares)	Biotech Crops
1	**USA***	**71.5**	Maize, soybeans, cotton, alfalfa, canola, sugar beets, potatoes, papaya, squash, apples
2	**Brazil***	**52.8**	Soybeans, maize, cotton, sugarcane
3	**Argentina***	**24.0**	Soybean, maize, cotton, alfalfa
4	**Canada***	**12.5**	Canola, soybeans, maize sugar beets, alfalfa, potatoes
5	**India***	**11.9**	Cotton
6	**Paraguay***	**4.1**	Soybeans, maize, cotton
7	**China***	**3.2**	Cotton, papaya
8	**South Africa***	**2.7**	Maize, soybeans, cotton
9	**Pakistan***	**2.5**	Cotton
10	**Bolivia***	**1.4**	Soybeans,
11	**Uruguay***	**1.2**	Soybeans, maize
12	**Philippines***	**0.9**	Maize
13	**Australia***	**0.6**	Cotton, canola, safflower

14	**Myanmar***	**0.3**	Cotton
15	**Sudan***	**0.2**	Cotton
16	**Mexico***	**0.2**	Cotton
17	**Spain***	**0.1**	Maize
18	**Colombia***	**0.1**	Maize, cotton
19	**Vietnam***	**0.1**	Maize
20	**Honduras**	**<0.1**	Maize
21	**Chile**	**<0.1**	Maize, canola
22	**Malawi**	**<0.1**	Cotton
23	**Portugal**	**<0.1**	Maize
24	**Indonesia**	**<0.1**	Sugarcane
25	**Bangladesh**	**<0.1**	Brinjal/Eggplant
26	**Nigeria**	**<0.1**	Cotton
27	**Eswatini**	**<0.1**	Cotton
28	**Ethiopia**	**<0.1**	Cotton
29	**Costa Rica**	**<0.1**	Cotton, pineapple
	Total	190.4	

Note: *19 biotech mega-countries growing 50,000 hectares, or more, of biotech crops

Biotech crops have expanded beyond the big four (maize, soybeans, cotton, and canola) to give more choices for many of the world's consumers and food producers. These GM crops include alfalfa (1.3 million hectares), sugar beets (473,000 hectares), sugarcane (20,000 hectares), papaya (12,000 hectares), safflower (3,500 hectares), potatoes (2,265 hectares), eggplant (1,931 hectares), and less than 1,000 hectares of squash, apples, and pineapple (ISAAA, 2019).

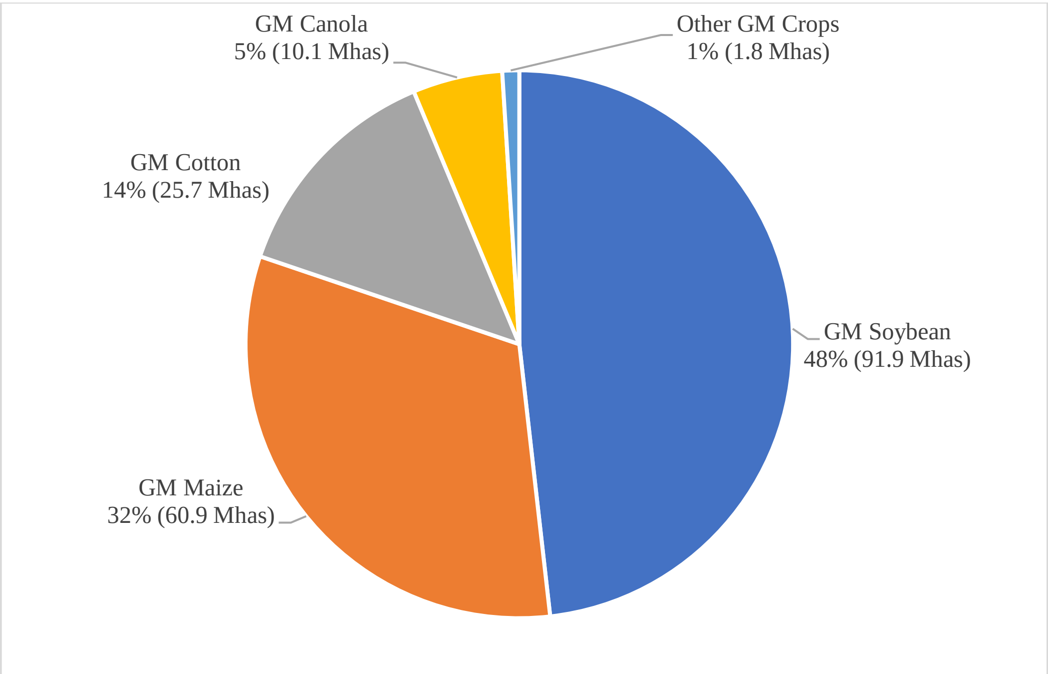

Figure 1: GM crops in 2019 (area and adoption rate) (ISAAA, 2019).

3.2 Genetically modified crops in Bangladesh:

There is only one approved genetically modified crop in Bangladesh, which is Bt-brinjal. Bt-brinjal is developed for controlling a serious pest of brinjal, brinjal fruit and shoot borer (BFSB), *Leucinodes orbonalis* Guenée. After successfully breeding EE-1 (Insertion of cry1Ac gene, under the control of the constitutive 35S CaMV promoter, into eggplant/brinjal termed "event" EE-1) into nine local OP varieties, Bangladesh Agricultural Research Institute (BARI) applied to the National Technical Committee on Crop Biotechnology (NTCCB) for their release. Following the recommendation from the NTCCB, the application for release was forwarded to the National Committee on BioSafety. The Bangladesh government granted approval for four genetically modified varieties of insect-resistant Bt-brinjal to be used for seed production and commercialization on October 30, 2013 (Shelton et al., 2019).

Figure 2: Four approved Bt-brinjal varieties in Bangladesh under cultivation (Shelton et al., 2019).

3.2.1 Mode of action of Bt-Toxin produced in Bt-brinjal:

In Bt-brinjal, Cry1Ac gene is isolated from the *Bacillus thuringiensis*, a soil-dwelling bacteria and inserted into brinjal. The Bt protein is activated in the alkaline stomach of the insect and attaches to the gut wall after the BSFB larvae consume plant portions that have the Cry1Ac gene inserted into them. The gut wall then disintegrates, allowing the Bt spores to invade the insect's body cavity (Paul et al., 2022). The Cry1Ac structure typically consists of seven different domains. D-I through D-VII make up the domain (D) number. They include four protoxin domains (D-IV, D-V, D-VI, and D-VII) and three canonical toxin core domains (D-I, D-II, and D-III). The sickle-shaped Cry1Ac-FL structure (Figure 3) has a toxic core that resembles the handle and protoxin domains that resemble the blade (Evdokimovet al., 2014).

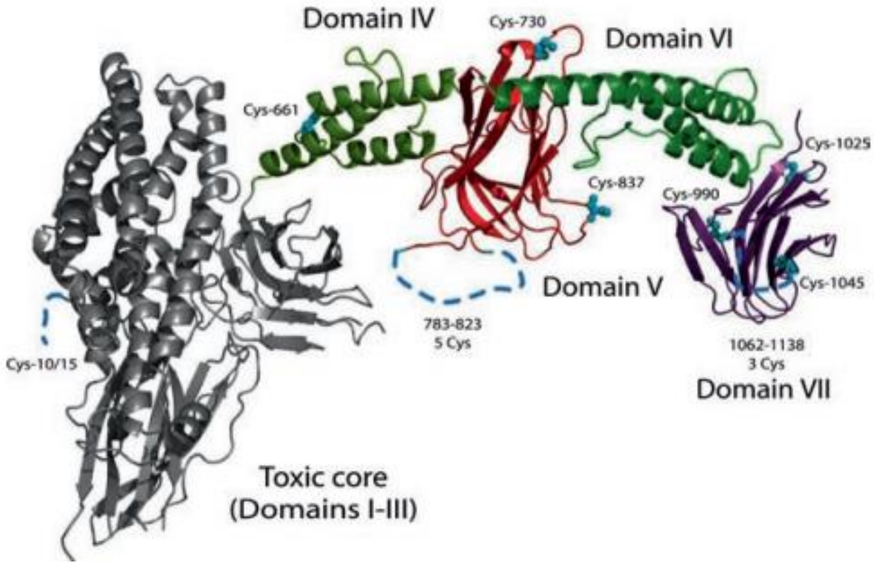

Figure 3: The general structure of the monomer Cry1Ac (Evdokimovet al., 2014).

3.2.2 Adoption of Bt-brinjal in Bangladesh:

Bt-brinjal cultivation began in early 2014 in the spring season. The seedlings of four Bt-brinjal varieties were distributed to 20 small brinjal farmers on 22 January 2014, which were carefully monitored and adapted for cultivation in four regions: Gazipur, Jamalpur, Pabna, and Rangpur. In total, 2.6 hectares of land were used for Bt-brinjal cultivation. Each region was assigned a specific Bt-brinjal variety, with Bt-brinjal-1 (Uttara) being planted in Rajshahi, Bt-brinjal-2 (Kajla) in Barisal, Bt-brinjal-3 (Nayantara) in Rangpur and Dhaka, and Bt-brinjal-4 (Iswardi/ISD006) in Pabna and Chittagong (Haque and Saha., 2020). Bt brinjal was made available to growers for demonstration trials. In 2014-2015, BARI provided seeds or transplants to its On-Farm Research Division to conduct research/demonstration trials on 108 farmer fields in 19 districts. In 2015-2016 and 2016-2017, demonstration trials were conducted in 250 farmer fields in 25 districts and 512 farmer fields in 36 districts, respectively. In 2017-2018, BARI provided seeds to 569 farmers in 40 districts. In addition to distribution by BARI, seeds were distributed to farmers through the Department of Agricultural Extension (DAE) to 6000 and 7001 farmers in 2016-2017 and 2017-2018, respectively. Bangladesh Agricultural Development Corporation (BADC) sold seeds to an additional 17,950 farmers in 2018. Altogether, more than 27,000 farmers had access to Bt brinjal in 2018. (Mondal and Akhter., 2018; Shelton et al., 2018). It's possible that the actual estimate is even greater because the seeds being distributed are open-pollinated, which allows growers to save and use seeds from previous years

Table. 2. Farmer adoption of Bt-brinjal in Bangladesh by source of seed. Figures do not include farmer-saved seed (Shelton et al., 2020)

Year	**Number of farmers**				**Area in production (ha)**			
	BARI	BADC	DAE	Total	BARI	BADC	DAE	Total
2013-14	20	0	0	20	2.83	0	0	2.8
2014-15	108	0	0	108	16.6	0	0	14.6
2015-16	250	0	0	250	10.1	0	0	10.1
2016-17	512	6000	0	6512	20.6	485.6	0	506.3
2017-18	581	6601	19430	27612	38.9	567.8	676.3	1392.9
2018-19	225	7070	13400	20695	15.0	656.0	542.3	1213.3

This table is a proof of rapid adaptation and farmers are getting benefit from Bt technology, and the target pest reduction through built-in toxin mechanism is working successfully in the field level.

3.2.3 Compatibility of Bt-brinjal in pest management practices:

Brinjal, *Solanum melongena* L. is one of the most important, inexpensive and popular vegetable crops grown and consumed in Bangladesh. The biggest constraint to eggplant production throughout Asia is the chronic and widespread infestation by the brinjal fruit and shoot borer (BFSB), *Leucinodes orbonalis* Guenée (Lep.: Crambidae) (Figure 4). Infestation levels may exceed 90% and the yield loss has been estimated up to 86% in Bangladesh (Anderson et al., 2019). It has been reported that 98% of Bangladeshi farmers relied solely on insecticide applications to control BFSB (Karim, 2004) and farmers spray insecticide nearly every day or every alternate day with as many as 84 applications during a 6-7 month cropping season (Anderson et al., 2019).

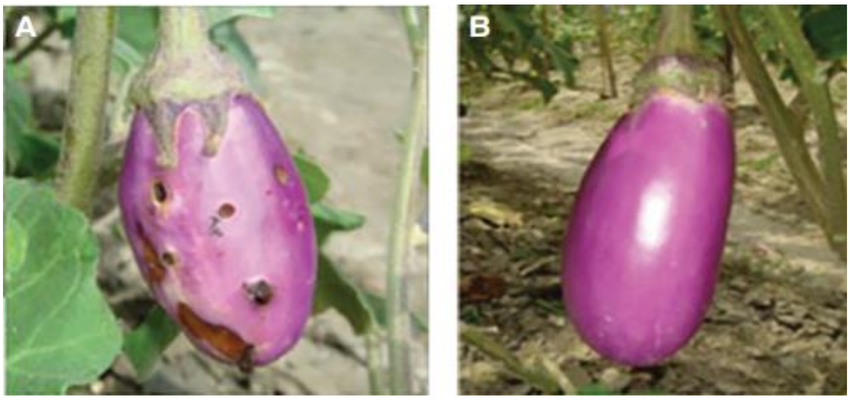

Figure 4: Comparison of Uttara brinjal variety showing injury by (A) the BSFB to non-Bt brinjal, and (B) lack of injury in Bt-brinjal (Shelton et al., 2019).

Such heavy reliance on insecticides, including broad-spectrum organophosphate, carbamate and pyrethroid insecticides, has been implicated in negative effects on human health and the environment (Dasgupta et al., 2005). Studies have shown that Bt brinjal provides nearly complete control of BFSB and dramatically reduces insecticide use, providing tremendous economic, health, and environmental benefits to farmers (Shelton et al., 2018). As with effective host plant resistance technology for insects, the reduced need to spray for the key pest (BFSB) will have cascading effects in the agro-ecosystem and affect integrated pest management (IPM) tactics. For example, other tactics will be needed to control the complex of "sucking insect pests," but this can be done through use of more selective insecticides or through enhanced biological control through conservation of natural enemies (Anderson et al., 2019).

3.2.3.1 Pest infestation status of Bt-brinjal:

BARI conducted different trials and found that Bt-brinjal performed much better than non-Bt eggplant. The infestation of fruit in Bt eggplant was very low, ranging from 0.04-0.88%, whereas it was much higher in non-Bt brinjal, ranging from 48-57%. (Mondal et al., 2016). A study was conducted by Prodhan et al., in 2018 to study the effect of spray and no-spray in Bt and non-Bt isolines of brinjal varieties. Significant differences were observed among the varieties for BFSB infestation (Table 3). There was no shoot and fruit infestation by BFSB in any of the four Bt-brinjal varieties in both spray and no-spray treatment. But lower infestation was observed in shoot of non-Bt isolines varieties compared to fruit in both sprays (0.61-2.24%) and no-spray (0.92-1.75%) treatment. The infested fruit in both spray and no-spray was higher in non-Bt isoline brinjal varieties. The range of infestation was 32.38-44.30% in spray and 10.93-35.21% in no-spray treatment. In both the spray and no-spray conditions, the non-Bt isoline-1 produced the maximum number of infested fruits (44.30 and 35.21 %). The level of fruit infestation was measured by the percentage of fruit weight, which is important for income as brinjal is sold by weight, and fruit with infestation is worth less (Prodhan et al., 2018).

Table 3. Mean infestation in brinjal by brinjal shoot and fruit borer (BFSB) (Prodhan et al., 2018)

Spray schedule	Variety	Infested shoot (%)	Infested fruit by No. (%)	Infested fruit by wt. (%)
Spray	BARI Bt begun-1	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	BARI Bt begun-2	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	BARI Bt begun-3	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	BARI Bt begun-4	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	Non-Bt isoline-1	1.14 (0.32) b	45.51 (0.03) a	44.30 (0.02) a
	Non-Bt isoline-2	0.61 (0.06) b	34.25 (0.08) ab	36.88 (0.08) ab
	Non-Bt isoline-3	2.24 (0.09) a	41.79 (0.25) a	40.14 (0.21) a
	Non-Bt isoline-4	1.60 (0.12) ab	29.82 (0.33) ab	32.38 (0.45) ab
No-spray	BARI Bt begun-1	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	BARI Bt begun-2	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	BARI Bt begun-3	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	BARI Bt begun-4	0.00 (0.00) c	0.00 (0.00) d	0.00 (0.00) d
	Non-Bt isoline-1	1.43 (0.14) ab	36.97 (0.34) a	35.21 (0.41) ab
	Non-Bt isoline-2	0.92 (0.13) ab	18.38 (0.43) bc	18.31 (0.38) bc
	Non-Bt isoline-3	1.75 (0.16) ab	11.33 (0.35) c	10.93 (0.37) c
	Non-Bt isoline-4	1.39 (0.10) ab	11.47 (0.28) c	10.99 (0.23) c

Note: Figures in parenthesis are standard error (SE) values; means followed by the same letter in a column within a year do not differ significantly by honestly significant difference (HSD) at 5% level.

3.2.3.2 Insecticide use status of Bt-brinjal:

The transgenic Bt brinjal successfully repels the BSFB pest, and as a result, farmers can reduce the use of pesticide. Reduction of pesticides application and less exposure of farmers to toxicity refect positive environmental outcomes (Hautea et al., 2016). Table 4 focuses on pesticide use by Bt and non-Bt farmers. In 2017, farmers sprayed 29 (Bt) to 33 times (non-Bt) for all pests. BFSB accounted for a large share of these applications, with Bt farmers spraying 11 times and non-Bt farmers spraying 12.8 times for BFSB on average. In 2018, non-Bt farmers sprayed on average 21.5 times, while Bt farmers sprayed 13.9 times. Much of this reduction in overall spraying frequency by Bt farmers can be attributed to reduced pesticide application for BFSB. To control for BFSB infestation, non-Bt farmers sprayed as much as 5.5 times more often than treatment farmers. Non-Bt households showed a decrease in the average number of sprays used for all pests, possibly due to increased use of IPM techniques. However, the reduction was not as significant as that seen in Bt farmers (Ahmed et al., 2019).

Table 4. Number of times pesticides were applied (Ahmed et al., 2019)

	2017		2018	
Average number of sprays	Treatment	Control	Treatment	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	12.8	1.4	7.7

Note: n= Number of plots.

Table 5 displays the use of pesticides in ml or gm per ha for Bt and non-Bt households. In 2017, Bt households used 17,948.0 ml or gm of pesticides per ha while non-Bt households used 20,587.7 ml or gm of pesticides per ha, with one-third of the amounts used for BFSB. In 2018, the amount of pesticides used by Bt and non-Bt farmers were 11,451 ml or gm per ha and 16,270 ml or gm per ha, respectively. This implies that Bt farmers used approximately 4,800 fewer ml or gm per ha of pesticides compared to non-Bt farmers. Furthermore, non-Bt farmers applied nearly five times the amount of pesticides that Bt farmers did for BFSB infestation (Ahmed et al., 2019).

Table 5. Quantity of pesticides used (Ahmed et al., 2019)

	2017		2018	
Quantity (gm or ml per ha)	Treatment	Control	Treatment	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

Note: n= Number of plots.

Table 6 shows that the costs of pesticide application follow a similar pattern. As the three measures of pesticide use are strongly linked, the difference in variation between the Bt and non-Bt groups remains the same. Bt-brinjal farmers reported that their crop required less pesticide than non-Bt varieties, resulting in greater savings (Ahmed et al., 2019).

Table 6. Cost of pesticides used (Ahmed et al., 2019)

Cost (Tk per ha)	2017		2018	
	Treatment	Control	Treatment	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

Note: n= Number of plots.

The data on percentage of farmers using pesticides of varying toxicity levels for BFSB are graphically presented in figure 5 below.

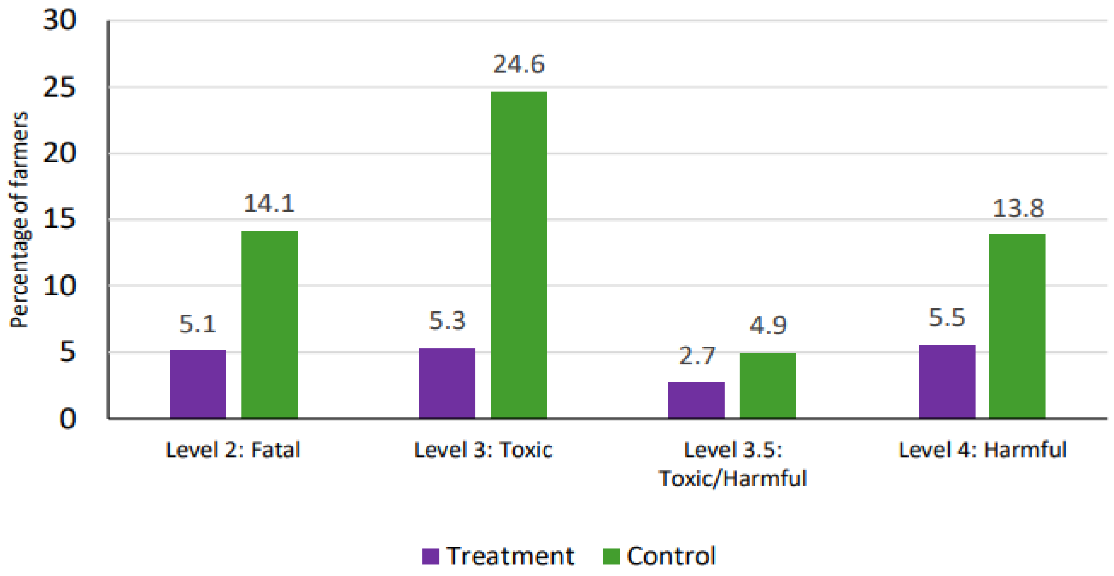

Figure 5: Percentage of farmers using pesticides for BSFB by toxicity level (Ahmed et al., 2019).

3.2.4 Ecological compatibility of Bt-brinjal:

It is a well-known fact that virtually no technology can be one hundred percent safe. To know the ecological impacts of Bt-brinjal, several scientists has examined the impact of the Bt protein Cry1Ac on non-target organisms, soil microflora of soil and variations in pests and disease susceptibility in 2018 (Prodhan et al., 2018; Quamruzzaman, 2021).

3.2.4.1 Impact on non-target organisms

Effect on pest species: As Cry1Ac can harm certain species of Lepidoptera, tests were conducted to evaluate its impact on non-target arthropods. These tests involved exposing a variety of non-target arthropods to concentrated Cry1Ac protein to support the environmental risk assessment of crops containing Cry1Ac. The results revealed that none of the tested organisms were significantly affected by Cry1Ac at high concentrations, indicating that cultivating Bt-brinjal is unlikely to have any harmful effects on non-target organisms (CERA, 2011). To further confirm this, BARI conducted several field trials between 2010 and 2013, which demonstrated that Cry1Ac as expressed in Bt-brinjal did not adversely affect non-target pests such as aphids, jassids, whitefly, and epilachna beetle. (Prodhan et al., 2018).

Effect on Pollinators: As a vital nontarget organism in many ecosystems, honey bees (*Apis mellifera* L.) play a critical role in pollinating various plants. During their foraging period, honey bees are likely to come into contact with genetically engineered (GE) crops, particularly insect-resistant crops that produce toxins designed to target specific insects. Given the important role of honey bees in pollination, it is essential to investigate the potential impacts of GE crops on these valuable pollinators. In recent studies, the potential impact of GE crops on honey bees has been examined, with a particular focus on the effects of Cry proteins, which are commonly used in insect-resistant GE crops. The studies aimed to determine whether Cry proteins have any adverse effects on honey bees, particularly on their survival and overall health. Based on the findings of these studies, it has been concluded that Cry proteins do not have any significant adverse effects on the successful survival of honey bees. This suggests that GE crops that utilize Cry proteins are unlikely to cause harm to honey bees or impact their role in pollination. (Ricroch et al., 2018).

Effect on Biological Control Agents: Biological control, popularly known as Biocontrol, a method used to manage harmful pests such as weeds, plant diseases, insects, and mites, involves the use of other beneficial organisms. Natural enemies of insect pests such as pathogens, predators, competitors, and parasitoids can be considered as biological control agents. In the case of BSFB, natural enemies include predators like praying mantis, ladybird beetles, earwig, green lacewing, and spiders. Experimental results have shown that Bt brinjal is highly effective in suppressing pests. Additionally, no adverse effects on non-target arthropods, including beneficial organisms that provide important ecosystem services as biocontrol agents, have been observed in the system. In a separate study, the Cry proteins of Bt crops used to control Lepidopteran insects have been confirmed to have no harmful effects on the essential natural biocontrol agents of these and other pest species (Prodhan et al., 2018). Another study concluded that Bt crops and biocontrol agents can be used together as effective measures for pest management without any negative impact on beneficial organisms. (Shelton et al., 2016).

3.2.4.2 Effect on Soil microflora

Bt eggplant cultivated soil was examined by BARI to analyze the effect of Cry1Ac protein on soil microflora. The studies were conducted on multiple locations using 9 Bt eggplant varieties and their non-Bt counterparts during 2010- 13. Soil samples were taken to study the effect of Cry1Ac on commonly found soil microorganisms such as Azotobacter, Rhizobium and populations of phosphate solubilising bacteria in the soil and analyzed in the Soil Microbiology Laboratory at BARI and its stations using standard microbiological procedures. The results show that the soil microflora is not dependent on the Bt trait gene present in eggplant and confirmed that the Cry1Ac protein has no toxic effect on soil microflora was found (Quamruzzaman, 2021).

3.2.4.3. Crossability

The genus Solanum is a very large genus to which eggplant belongs and have a wide diversity and have the classification of cultivar into several phenotypic groups. Wild species such as *S. indicum, S. sisymbriifolium, S. nigrum* and *S. torvum* were not cross compatible with the cultivated S. melongena. A few seeds were produced while crosses were done among the of the cultivated S. melongena with wild *S. torvum*, but those seeds failed to germinate (Narasimha Rao, 1980). It was also found that S. melongena was crossable with *S. incanum*. However, even though they are crossable, S. melongena and *S. incanum* co-exist in nature since long time with their diversity in nature and there is no chance to decreased (Quamruzzaman, 2021).

3.2.4.4. Outcrossing of eggplant

Eggplant is a highly self-pollinated crop, while a certain percentage of outcrossing can occur. When the stigma is parallel to anthers generally occurs self-pollination; there is a great chance for cross-pollination, while the stigma develops beyond the anthers. Generally, the natural cross pollination mainly depends on variety, season, location, environmental condition, and pollinator activity. The findings of out-crossing have been reported in China (3 to 7%) and at

AVRDC (0 to 8.2%) (Chen and Li, 2000). The outcrossing studies conducted by Mahyco for Event EE-1 derived hybrids reported 0.07% to 2.7% (Quamruzzaman, 2021).

3.2.4.5. Pollen flow

A study was conducted by Mahyco in India to assess the potential for outcrossing in S. melongena with sexually compatible wild species and related species that share genetic compatibility. According to the study conducted by Mahyco on the Bt eggplant lines developed at Mahyco, pollen traveled a maximum distance of 15-20 meters, and outcrossing ranged from 1.46-2.7%. The study also demonstrated that Bt-brinjal did not exhibit any weediness and behaved similarly to non-Bt isolines (Mahyco, 2008). The findings revealed that genetic modification did not alter the outcrossing potential of S. melongena. It is worth noting that since eggplant pollen can travel a relatively short distance, unintentional outcrossing of Bt-brinjal to non-Bt brinjal varieties can be easily prevented (Quamruzzaman, 2021).

3.2.4.6. Gene transfer from eggplant to other organisms

Horizontal gene transfer from plants to microorganisms or animals, humans is totally unlikely. No evidence has been identified for any mechanism by which plant genes could be transferred to any animals or humans, nor any evidence that such gene transfer has occurred for any plant species during evolutionary history, since animals and humans are eating a large quantities of plant DNA for a long time. So, there is no chance of brinjal genes transferring to humans and other animals. Likewise, gene transfer from any other plant or brinjal to microorganisms is totally ridiculous. Under the natural condition, horizontal gene transfer from plants to bacteria has not been experimentally demonstrated (Nielsen et al.,1998) and deliberate attempts have so far failed to induce such transfers (Keese, 2008).

3.2.4.7. Germination, Aggressiveness and Weediness

A study conducted by BARI aimed to evaluate the germination rate of Bt-brinjal by comparing it with its non-Bt counterpart in soil. The study found no significant differences in the germination rate or vigour between Bt and non-Bt brinjal lines. Additionally, the weediness potential of Bt-brinjal was compared with a non-Bt counterpart by analyzing their phenotypic characteristics. The results showed that there were no observable differences in weediness or aggressiveness potential between the two types of brinjal. Mahyco also conducted a sequence analysis to monitor the aggressiveness of Bt-brinjal as compared to its isogenic counterparts. It was observed that eggplant, in general, does not possess any traits that contribute to weediness, such as seed dormancy, soil persistence, rapid vegetative growth, a short life cycle, high seed output, and dispersal (Quamruzzaman, 2021).

3.2.5 Compatibility of Bt-brinjal with conventional varieties:

3.2.5.1 Cost of Production:

In brinjal cultivation, the main cost is pesticides, but in case of Bt-brinjal varieties, there was less pesticide required than the regular varieties. Because Bt-brinjal deters BSFB, so no spraying is required for that pest. Spraying once in a week was enough for Bt-brinjal to control other paste, whereas non-Bt varieties required as often as three times a week. This is financial savings for farmers (Ahmed et al. 2019). The researchers stated features which provided a breakdown of input costs per ha for treatment farmers cultivating Bt brinjal (Bt begun-4) and control farmers growing non-Bt brinjal (ISD-006) (Table 7).

Table 7. Input costs per hectare for Bt brinjal (Bt begun-4) and non-Bt brinjal (ISD-006) cultivation (Paul et al., 2022)

Inputs	**Cost of production (BDT per ha)**	
	Bt-brinjal	Non-Bt brinjal
Seed/seedlings	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

The total costs of production for Bt-brinjal per ha (BDT 72,109) were lower than non-Bt brinjal (BDT 81,902). The total gains in terms of input cost (BDT 9793) were mainly due to considerably less spent by Bt-brinjal farmers on pesticides compared to the non-Bt farmers (Ahmed et al., 2019).

3.2.5.2 Return:

Another study which was conducted by Rashid et al., (2018), and the results were presented in Table 8. They revealed that gross returns from Bt-brinjal cultivation were (Bangladeshi Taka) BDT 394,570/ha as compared to BDT 312,945/ha for non-Bt brinjal. In case of net returns, the amount was BDT 179,602/ha for Bt-brinjal which was five times larger as compared to BDT

29,841/ ha for non-Bt. The yield difference between the two groups was only 3.02 tons, but the non-Bt farmers applied almost three times more pesticides as well as more fertilizer to maintain the yields. The sprayed pesticide costs were BDT 14,215/ha for Bt-brinjal and BDT 36,057 for non-Bt brinjal. As a result, the net returns were higher in case of Bt- brinjal than non-Bt brinjal due to lower production costs and higher yields. Based on total cost, production cost of Bt-brinjal was BDT 9.26/kg, and for non-Bt brinjal, it was BDT 14.20/kg (Rashid et al., 2018)

Table 8. Per hectare return from eggplant production in the study areas (Paul et al., 2022)

Items	Return (BDT/ha)	
	Bt-brinjal	Non-Bt brinjal
Fresh eggplant yield (ton/ha)	394,570	312,945
Gross return	394,570	312,945
Gross margin	248,651	101,590
Net return	179,602	29,841
Beneft cost ratio	1.84	1.11
Production cost (total cost basis) (BDT/kg)	9.26	14.02

3.2.5.3 Market price:

Surveying the market price Bt and non-Bt brinjal at both retail and wholesale levels, researchers found that Bt prices are higher than non-Bt prices at both the retail and wholesale levels (Table 9) (Ahsanuzzaman and Zilberman, 2018).

Table 9. Market price information of Bt and non-Bt eggplant (Ahsanuzzaman and Zilberman, 2018)

Items	Price (BDT/Kg)		Bt premium (%)
	Bt brinjal	Non-Bt brinjal	
Wholesale	15.45	11.7	32
Retail	28.6	22.35	28
Mark up	13.5	10.65	27

A higher wholesale price suggested that farmers were receiving higher prices, while higher retail prices indicated that consumers were willing to pay more for Bt brinjal varieties.

3.3 Other GM crops waiting for approval in Bangladesh:

3.3.1 Bt-cotton:

Two Bt-cotton varieties are waiting for approval in Bangladesh. Bt-cotton provides protection against a serious pest of cotton, cotton ball worm *Helicoverpa armigera*. Cotton ball worm causes severe damage in the yield of cotton lint. It is believed that, these two varieties will increase cotton yield from 3 tonnes per to 4 tonnes per hectare. Aside from increased yield, farmers can also save pesticide costs against bollworms (ISAAA, 2020).

3.3.2 Golden rice:

Golden Rice is a genetically modified variety of rice that contains beta-carotene, a source of vitamin A, which is lacking in the diets of many people in developing countries, including Bangladesh. Bangladesh has one of the highest rates of vitamin A deficiency in the world, which can cause blindness, weakened immune system, and even death. In response to this problem, the Bangladesh Rice Research Institute (BRRI) and the International Rice Research Institute (IRRI) developed Golden Rice. But regulatory approval has remained pending for the last five years, hindering its cultivation in farmers' fields (Stokstad, 2019).

3.3.3 Blight resistant potato:

BARI has developed the blight resistant (RB) potato, applied on December 29, 2016, not yet been approved. Rb potato will provide protection against late blight of potato *Phytophthora infestans*. Rb potato could save Tk 100cr an yearr in pesticide cost in Bangladesh (Ahmad, 2017).

CHAPTER IV

CONCLUSION

In Bangladesh, Bt-brinjal is the only approved GM crop. Its ecological impacts and combability with pest management practices are analysed in this seminar paper. The result shows that, in case of adaptability of GM crops in pest management practices, Bt-brinjal reduces the % infestation of fruit by both number and size. As the abundance of of BSFB reduces, the number of insecticide usage, the quantity and cost of insecticide usage reduces significantly in Bt-brinjal.

There are no significant adverse impacts on non-target organisms, such as, other pest, pollinators and natural enemies. Adverse effects on soil organisms were not found. There is no evidence of unwanted outcrossing, cross ability with wild species, horizontal gene transfer, weediness and aggressiveness of Bt-brinjal. In comparison with conventional brinjal verities, Bt-brinjal shows lower cost of production, higher net return as well as higher market price.

Although the seminar paper on Bt-brinjal in Bangladesh presents positive findings on the ecological impacts and compatibility with pest management practices, there are still several knowledge gaps and future suggestions that need to be addressed. One of the major knowledge gaps is the long-term impact of Bt-brinjal on soil health and biodiversity. Additionally, there is a potential for resistance development in target pest populations, which needs to be monitored closely. Further research is needed to understand the ecological impact on non-target organisms in the long run, especially pollinators and natural enemies. Another concern is the potential for gene flow and outcrossing to wild species. It is essential to continuously monitor and prevent unwanted gene flow to maintain the genetic integrity of wild relatives.

References:

Ahmad, R. A. (2017, January 5). *Second GM crop ready for release*. The Daily Star. Retrieved March 20, 2023, from https://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=19551

Ahmed, A. U., Hoddinott, J. F., Islam, K. M. S., Khan, A. S. M. M. R., Abedin, N., Hossain, N. Z., & Zubaid, S. (2019). Impacts of Bt brinjal (Eggplant) technology in Bangladesh. *Project Report prepared for the US Agency for International Development (USAID)*.

Ahsanuzzaman, A., & Zilberman, D. (2018). Bt eggplant in Bangladesh increases yields and farmers' Incomes, and reduces pesticide use. *ARE Update, 22*(2), 5-8.

Anderson, J. A., Ellsworth, P. C., Faria, J. C., Head, G. P., Owen, M. D., Pilcher, C. D., & Meissle, M. (2019). Genetically engineered crops: importance of diversified integrated pest management for agricultural sustainability. *Frontiers in bioengineering and biotechnology*, *7*, 24.

CERA. (2011). A review of the environmental safety of the Cry1Ac protein. *Environmental Biosafety Research*, *10*(2), 27-49

Chen, N. C., & Li, H. M. (2000). Vegetable production training manual. *Asian Vegetable Research and Development Center, Tainan*.

Cho, J., Park, S., Lee, G., Kim, S., Lim, S., Kim, Y., & Park, S. (2020). Current Status of GM Crop Development and Commercialization. *Korean Journal of Breeding*, *52*(S), 40-48.

Dasgupta, S., & Meisner, C. (2005). *Health effects and pesticide perception as determinants of pesticide use: evidence from Bangladesh* (Vol. 3776). World Bank Publications.

Evdokimov, A. G., Moshiri, F., Sturman, E. J., Rydel, T. J., Zheng, M., Seale, J. W., & Franklin, S. (2014). Structure of the full-length insecticidal protein C ry1 A c reveals intriguing details of toxin packaging into in vivo formed crystals. *Protein Science*, *23*(11), 1491-1497.

Haque, M. S., & Saha, N. R. (2020). Biosafety Measures, Socio-Economic Impacts and Challenges of Bt-brinjal Cultivation in Bangladesh. *Frontiers in Bioengineering and Biotechnology*, *8*, 337.

Hautea, D. M., Taylo, L. D., Masanga, A. P. L., Sison, M. L. J., Narciso, J. O., Quilloy, R. B., & Shelton, A. M. (2016). Field performance of Bt eggplants (Solanum melongena L.) in the Philippines: Cry1Ac expression and control of the eggplant fruit and shoot borer (Leucinodes orbonalis Guenée). *PLoS One*, *11*(6), e0157498.

ISAAA (2022, June 22). *Bangladesh Approves 2 Bt Cotton Varieties*. Crop Biotech Update. Retrieved March 20, 2023, from https://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=19551

ISAAA. (2019). ISAAA Brief 55-2019: Executive Summary Biotech Crops Drive Socio-Economic Development and Sustainable Environment in the New Frontier. *International Service for the Acquisition of Agri-Biotech Applications*.

Karim, A. N. M. R. (2004, October). IPM for vegetable crops: issues and technology developments in Bangladesh. In *A keynote paper presented at the sixth biennial conference of Bangladesh Entomological Society held at BARI, Joydebpur, Gazipur, Bangladesh*.

Keese, P. (2008). Risks from GMOs due to horizontal gene transfer. *Environmental biosafety research*, *7*(3), 123-149.

Lundgren, J. G., Gassmann, A. J., Bernal, J., Duan, J. J., & Ruberson, J. (2009). Ecological compatibility of GM crops and biological control. *Crop Protection*, *28*(12), 1017-1030.

Mahmuda, R., Mondal, S., Rahman, A., Ahmed, M., Parvin, S., & Ahmed, T. (2022). Genetically Modified Crop vs Hybrid Crops and their Impact on Health and Environment. *European Journal of Nutrition & Food Safety*, *14*(2), 50-61.

Mahyco, (2008). Development of Fruit and Shoot Borer Tolerant Brinjal, *Maharashtra Hybrid Seeds Company Ltd., Mumbai*.

Martin, F. W., & Rhodes, A. M. (1979). Subspecific grouping of eggplant cultivars. *Euphytica*, *28*, 367-383.

Mondal, M. R. I., & Akter, N. (2018). Success on Bt brinjal in Bangladesh. *Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources Asia-Pacific Association of Agricultural Research Institutions. Bangkok, Thailand*.

Mondal, R. I., Quamruzzaman, A. K. M., Hasan, K., & Khanam, D. (2016, September). The journey of Bt eggplant in Bangladesh. In *Proceedings of the 4th Annual South Asia Biosafety Conference, (Hyderabad)*.

Narasimha Rao, N. (1979). Barriers to hybridization between Solanum melongena and some other species of Solanum. In *Linnean Society symposium series*.

Nielsen, K. M., Bones, A. M., Smalla, K., & van Elsas, J. D. (1998). Horizontal gene transfer from transgenic plants to terrestrial bacteria–a rare event? *FEMS microbiology reviews*, *22*(2), 79-103.

Paul, S. K., Mahmud, N. U., & Islam, T. (2022). Impacts of Bt brinjal on economic benefit of farmers and environmental sustainability in Bangladesh. In *Bacilli in agrobiotechnology: plant stress tolerance, bioremediation, and bioprospecting* (pp. 539-560). Cham: Springer International Publishing.

Prodhan, M. Z. H., Hasan, M. T., Chowdhury, M. M. I., Alam, M. S., Rahman, M. L., Azad, A. K., & Shelton, A. M. (2018). Bt eggplant (*Solanum melongena* L.) in Bangladesh: Fruit production and control of eggplant fruit and shoot borer (*Leucinodes orbonalis* Guenee), effects on non-target arthropods and economic returns. *PLoS One*, *13*(11), e0205713.

Quamruzzaman, A. K. M. (2021). The first gm crop in bangladesh–bt eggplant. *European Journal of Agriculture and Food Sciences*, *3*(2), 45-55.

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

Ricroch, A., Akkoyunlu, S., Martin-Laffon, J., & Kuntz, M. (2018). Assessing the environmental safety of transgenic plants: honey bees as a case study. In *Advances in botanical research* (Vol. 86, pp. 111-167). Academic Press.

Sharma, P., Singh, S. P., Iqbal, H. M., Parra-Saldivar, R., Varjani, S., & Tong, Y. W. (2022). Genetic modifications associated with sustainability aspects for sustainable developments. *Bioengineered*, *13*(4), 9509-9521.

Shelton, A. M., Hossain, M. J., Paranjape, V., Azad, A. K., Rahman, M. L., Khan, A. S. M. M. R., & McCandless, L. (2018). Bt eggplant project in Bangladesh: history, present status, and future direction. *Frontiers in Bioengineering and Biotechnology*, 106.

Shelton, A. M., Hossain, M. J., Paranjape, V., Prodhan, M. Z., Azad, A. K., Majumder, R., & Hossain, M. A. (2019). Bt brinjal in Bangladesh: the first genetically engineered food crop in a developing country. *Cold Spring Harbor Perspectives in Biology*, *11*(10), a034678.

Shelton, A. M., Romeis, J., Naranjo, S. E., Tian, J., & Hellmich, R. L. (2016). Use of Bt-resistant caterpillars to assess the effect of Cry proteins on beneficial natural enemies. *IOBC-WPRS Bulletin*, *114*, 51-55.

Shelton, A. M., Sarwer, S. H., Hossain, M. J., Brookes, G., & Paranjape, V. (2020). Impact of Bt brinjal cultivation in the market value chain in five districts of Bangladesh. *Frontiers in Bioengineering and Biotechnology*, 498.

Stokstad, E. (2019, November 20). *Bangladesh could be the first to cultivate Golden Rice, genetically altered to fight blindness*. Science | AAAS. Retrieved March 20, 2023, from https://www.science.org/content/article/bangladesh-could-be-first-cultivate-golden-rice-genetically-altered-fight blindness#:~:text=The%20Golden%20Rice%20under%20review,14%25%20of%20the%20national%20harvest.

World Health Organization. (2017). *20 questions on genetically modified foods*. Retrieved March 20, 2023, from https://www.who.int/foodsafety/areas_work/food-technology/faq-genetically-modified-food/en/

Yu, W., Alam, M., Hassan, A., Khan, A. S., Ruane, A., Rosenzweig, C., & Thurlow, J. (2010). *Climate change risks and food security in Bangladesh*. Routledge.