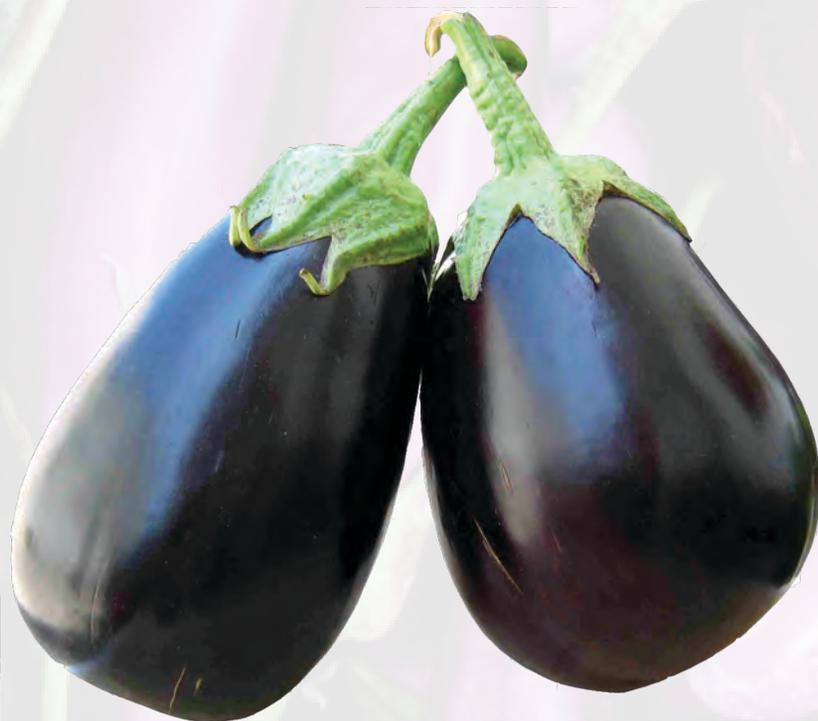




Success Story on *Bt* Brinjal in Bangladesh



Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources

Asia-Pacific Association of Agricultural Research Institutions

FAO Annex Building, 201/1 Larn Luang Road, Pomprap Sattrupai,
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Citation : APAARI (2018) Success Story on *Bt* Brinjal in Bangladesh. Asia-Pacific Association of Agricultural Research Institutions, Bangkok, Thailand. xviii+39 p.

Cover page photo identity

Front Cover : Bumper *Bt* brinjal crop in farmer's field

Back cover : A Bangladeshi farmer harvesting *Bt* brinjal crop

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ISBN : 978-616-710-111-8

Published by:

Asia-Pacific Association of Agricultural Research Institution (APAARI)

Under the:

Food and Agriculture Organization of the United Nation (FAO)

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Printed in September, 2018

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Foreword

During past 21 years, it has been ascertained that the commercialization of genetically modified (GM) crops, after the biosafety issues have been duly addressed, have delivered substantial agronomic, environmental, economic, health, and social benefits to farmers, and increasingly to the consumers. This is despite the fact that certain sections of the society are still skeptical on the development and cultivation of GM crops. Although, agricultural biotechnology is not a panacea to increase production and productivity, but the increasing trend of productivity due to GM crops have proved substantially that conventional crop technology alone cannot feed the burgeoning population which is more serious concern in the Asia and the Pacific. During 2017, up to 17 million farmers in 24 countries planted various GM crops on 189.8 million hectares farm area. Out of which about 100 million hectares belongs to developing countries which are the homes of smallholder farmers. Many countries in Asia-Pacific region, e.g. Australia, Bangladesh, China, India, Myanmar, Pakistan, Philippines and Vietnam, have adopted the cultivation of GM crops and the farmers of these countries have been benefitted economically.

Bangladesh started research work on development of *Bt* brinjal in 2005 in collaboration with Cornell University, USA, under Agricultural Biotechnology Support Project II (ABSP II) with financial support of United State Agency for International Development. After rigorous regulatory process, laboratory and field trials, *Bt* brinjal varieties were released in 2014 and made available to a few farmers for cultivation. Cultivation of *Bt* brinjal varieties were considered the best option by the farmers and the adoption of *Bt* brinjal varieties increased rapidly by about 7500 Bangladeshi farmers in 36 districts in 2017 with favorable socio-economic benefits. The advancement and development of *Bt* brinjal in Bangladesh was made possible because of government and people of Bangladesh have embraced the science-based technologies to improve the livelihoods of smallholder farmers.

I commend the efforts of the authors Dr Md. Rafiqul Islam Mondal and Ms Nasrin Akter to document the journey of *Bt* brinjal in Bangladesh which will serve as an example of what can be (i) achieved with science-based technologies to improve the livelihoods of smallholder farmers and (ii) contributed towards achieving the Sustainable Development Goals. I also sincerely appreciate the meticulous editing of the Success Story by Dr Rishi Tyagi, Coordinator of the program of Asia Pacific Consortium on Agricultural Biotechnology and Bioresources at APAARI.

I hope this document will be of great importance specially to scientists and policy makers of countries in Asia-Pacific Region and also elsewhere who are struggling to integrate the safe GM crops into their agricultural scenario.



Ravi Khetarpal

Executive Secretary, APAARI

Message

A document on **Success Story on *Bt* Brinjal in Bangladesh** has been prepared and presented the brinjal as vegetable, agriculture biotechnology, genetically modified (GM) crops, research initiatives at BARI, *Bt* brinjal controversy, seed production on *Bt* brinjal varieties, distribution of seedlings, progress on *Bt* brinjal cultivation in the farmers' fields and biosafety guidelines in Bangladesh.

I am happy to know that APAARI organized a Regional Expert Consultation on Agricultural Biotechnology – Scoping Partnership to Improve livelihoods of Farmers in Asia-Pacific, held in Bangkok, Thailand, during May 29-31, 2018 and one of the key-note papers entitled '**Success Story on *Bt* Brinjal in Bangladesh**' was presented by Dr Md. Rafiqul Islam Mondal, Former Director General, BARI, during the Consultation.

The present government, under the dynamic leadership of Hon'ble Prime Minister, Sheikh Hasina has given special priority in agriculture sector and has taken steps to make agriculture more profitable for the farmers. We are also thankful to our Hon'ble Agriculture Minister, Matia Chowdhury, MP, for her great role in releasing the *Bt* brinjal in Bangladesh in 2013.

To make sure sustainable agricultural production in Bangladesh, there is vital need for the advancement of agricultural biotechnology. Genetic engineering is a versatile tool for introducing new traits and breaking yield barriers. Over the past decade, GM crops productions have been gradually increased and captured strategic places in Bangladesh and GM technology plays a vital role to achieve economic and productivity gains, introduce resistance to pests, insects and diseases for biotic stresses, improve nutritional quality of food and enhance the durability of products during harvesting and delivery.

In Bangladesh, biotechnology research and development is drawing attention of both national and international collaborations. To ensure food security, the Government of Bangladesh is accelerating deregulation and research of genetically engineered (GE) crop varieties. Since approval of *Bt* brinjal (eggplant) in 2013, trials have been satisfactory and brinjal seeds are already being distributed to farmers. Additional GE research now includes development of new GE varieties of rice, potatoes, and cotton. Field trials have started for Golden rice and initial development has begun for a new GE potato variety with late blight resistance.

In addition, a rice variety having higher saline tolerance is also at initial trial stage. For cotton, government of Bangladesh is launching a new initiative to develop an improved *Bt* cotton variety. The Bangladesh Biosafety Rules (2012 BR) and 2007 Biosafety Guidelines of Bangladesh (2007 BG) officially created a regulatory framework and approval process for all GE products developed domestically or by a third country.

We are able to initiate *Bt* brinjal and thereby decrease in usage of toxic insecticides. This turn out to be good not only for the farmers who have to purchase far less pesticides but also for the environment. Currently, around 7500 farmers in 36 districts are cultivating four *Bt* brinjal varieties – BARI *Bt* Begun-1 (Uttara), BARI *Bt* Begun-2 (Kazla), BARI *Bt* Begun-3 (Nayantara) and BARI *Bt* Begun-4 (ISD 006). Farmers from Rajshahi, Rangpur, Pabna and Gazipur started cultivating *Bt* brinjal for the first time in 2014.

I would like to recognize the contribution made by Dr Md. Rafiqul Islam Mondal, Former DG, BARI, in preparing an inclusive document with vast information on research findings and development activities on *Bt* brinjal. I would like to thank scientists of BARI who worked hard directly or indirectly for the development of *Bt* brinjal. I also thank the team headed by Ronnie Coffman, Professor of International Agriculture of Cornell University, for his continuous support for the program. I would welcome receiving feedbacks, comments and suggestions from the readers for our future endeavours.



Md. Kabir Ikramul Haque, PhD
Executive Chairman
Bangladesh Agricultural Research Council (BARC)
Dhaka, Bangladesh

Message

I am delighted to note down a few words about this important document on '**Success Story on *Bt* brinjal in Bangladesh**'. The document highlights the brinjal as vegetable, agriculture biotechnology, GM crops, research initiatives of BARI on *Bt* brinjal, controversy over GM crops, seed production of *Bt* brinjal varieties, distribution of seedling, progress on *Bt* brinjal cultivation in the farmers' fields and biosafety guidelines in Bangladesh.

Agriculture is the dynamic force of Bangladesh and it is most important to keep up with agricultural innovations and research. The present agriculture-friendly government of Bangladesh, under the dynamic leadership of Hon'ble Prime Minister, Sheikh Hasina, has already given special emphasis for the development of agriculture sector and has taken up necessary steps to increase agricultural production. Bangladesh as a nation has made great strides forward in achieving food security in the country where the main problems are a growing population and changing climate.

To ensure sustainable agricultural production in Bangladesh, there is an urgent need for the advancement of agricultural technology. We would have to move towards biotechnology. Genetic engineering is a versatile tool for introducing new traits and breaking yield barriers. Over the past decade, GM crop production has been gradually increased and captured strategic places in Bangladesh. GM technology plays a vital role to achieve economic and productivity gains, introduce resistance to pests and diseases for biotic stresses, improve nutritional quality of food and enhance the durability of products during harvesting and delivery.

Bangladesh is a very innovation-friendly and able to introduce *Bt* brinjal, thereby reduce toxic insecticides use. This turn out to be good not only for the farmers but also for the consumers who have to purchase far less pesticides and also for the environment. Currently, more than 7500 farmers in 36 districts of Bangladesh are cultivating four *Bt* brinjal varieties. Farmers from Rajshahi, Rangpur, Pabna and Gazipur started cultivating *Bt* brinjal for the first time in 2014. With the journey of cultivating GM crops, I hope that scientists in Bangladesh will bring the new technology and produce rust-resistant wheat as well as rice. Now we need to work on biodiversity by public and private sector investment for R&D, IPR, appropriate policy and legislation of GM crop production at national and international level. Since 1901, when *Bacillus thuringiensis* (*Bt*) was first isolated, the science rapidly advanced. Today GM technique

is used in many crops. With the journey of cultivating *Bt* brinjal, Bangladesh has joined a group of 29 countries that grow GM crops.

Finally, I would like to appreciate the contribution made by Dr. Md. Rafiqul Islam Mondal, Former Director General, BARI in preparing this inclusive document by compiling the reports on research and development activities along with a lot of information on *Bt* brinjal of Bangladesh. I also express my sincere gratitude to APAARI for their help for compiling this document.

I hope that it will provide detail information on available resources and research activities related to *Bt* brinjal in Bangladesh, which may be useful for the other countries of the world.



Professor Khondoker Nasiruddin, PhD

Vice Chancellor

Bangabandhu Sheikh Mujibur Rahman Science & Technology University
Gopalganj, Bangladesh

Preface

Brinjal (*Solanum melongena* L.), popularly known as *Begun*, is a very important vegetable in Bangladesh which can be grown year-round *i.e.* in both seasons of winter and summer. It covers about 50 thousand hectares of land and produces about 0.50 million MT every year. In every family, it is a commonly used vegetable for a good source of vitamins and minerals. The major constraints of brinjal cultivation is the shoot and fruit borer which infests tender shoot tips and growing fruits and cannot be controlled easily by spraying insecticides because it lies inside the plant or fruits. Farmers spray insecticide frequently to control the insect but are unable to control effectively.

To address this problem, BARI started research work on *Bt* brinjal in 2005 with the Technical Cooperation of Cornell University, under Agricultural Biotechnology Support II (ABSP-II) project with the financial support of United States Agency for International Development (USAID). BARI conducted research program on *Bt* brinjal following Biosafety guidelines which was formulated by the Ministry of Environment and Forest (MoEF) in 2007. Research work was done at Biotechnology Division, BARI in collaboration with its Horticulture Research Centre (HRC), Entomology Division, Plant Pathology Division and Soil Science Division.

The seed production program was implemented by the Seed Technology Division and the farmers' field trials were conducted by On Farm Research Division (OFRD), BARI. After continuous efforts, four *Bt* brinjal varieties were approved by MoEF; and the Ministry of Agriculture (MoA) on October 30, 2013. Farmers' field testing started in January 2014 by distributing seedlings among 20 farmers by the Hon'ble Agriculture Minister, Matia Chowdhury, MP.

It started with 20 farmers from four districts in 2014 but the number of farmers has been increased to more than 7500 in 2017-18. In this whole developmental process of *Bt* brinjal, a large number of scientists, field workers, policy makers, administrators were involved. We thankfully acknowledge their efforts.

We should not silent as researchers. We should have the mentality to develop new technology and also to accept it. This technology is considered to be the best option for the farmers of a country like Bangladesh which faces the challenge of food security and decreasing cultivable land. We would like to thank the scientists of BARI who worked directly or indirectly for the development of *Bt* brinjal. We

also thank the team of Cornell University, headed by Ronnie Coffman, Professor of International Agriculture, College of Agriculture and Life Science, Cornell University, Ithaca, New York, for their continuous support for the program.

The Authors

Acknowledgements

At the outset, I would like to express my sincere gratitude to the Asia-Pacific Association of Agricultural Research Institution (APAARI) for identifying me to write a **Success Story on *Bt* Brinjal in Bangladesh**. Special thanks to Dr Ravi Khetarpal, Executive Secretary, APAARI, for his kind support. I am thankful to Dr Rishi Kumar Tyagi, Coordinator, Asia-Pacific Consortium on Agriculture Biotechnology and Bioresources (APCoAB) for his valuable help in formulating an outline for the document, critical editing, and valuable suggestions for improvement of the document. I would also like to thank Drs Khetarpal and Tyagi for inviting me to attend the Regional Expert Consultation on Agricultural Biotechnology – Scoping Partnership to Improve Livelihood of Farmers in Asia-Pacific, held during May 29-31 May, 2018 in Bangkok, Thailand.

I also acknowledge the financial support of the USAID and technical support of Cornell University, for the *Bt* brinjal programme in Bangladesh. I express my sincere appreciation to Dr Wais Kabir, Executive Director, Krishi Gobeshona Foundation (KGF) who inspired me to compile all the information on *Bt* brinjal of Bangladesh from the beginning of the research until now and also provided me with the official support from KGF to accomplish this task timely.

I am thankful to Dr Abul Kalam Azad, Director General, Bangladesh Agricultural Research Institute (BARI); Dr Md. Mahbubar Rahman Khan, Chief Scientific Officer (CSO), On Farm Research Division (OFRD), BARI; Dr Dil Afroz, CSO, Biotechnology Division, BARI; Dr Ferdousi Islam, Principal Scientific Officer (PSO), Horticulture Research Centre (HRC), BARI; Dr Md. Abdur Rashid, PSO, Agri-Economics Division, BARI; Dr Md. Nazmul Islam, Scientific Officer of Seed Technology Division, BARI, for providing me relevant and valuable information on *Bt* brinjal from BARI.

Sincere appreciation goes to Dr Tapan Kumar Dey, Former Director, Tuber Crops Research Centre (TCRC), BARI and Dr Shahabuddin Ahmad, Former Director, HRC, BARI for their continuous support during last few months to write the success story of *Bt* brinjal in Bangladesh. Special thanks to Dr Md. Abdul Aziz, Former Director, TCRC, BARI, for critically going through the manuscript for its improvement.

I would also like to thank Dr Kabir Ikramul Haque, Executive Chairman, BARC and Dr Aziz Zilani Chowdhury, Member Director (Crops), BARC, for providing me with information on the ABSP II Project and other information on *Bt* brinjal which

are very much related to this document. Many thanks to my co-author Ms Nasrin Akter, Communication Specialist, KGF and Dr Sufara Akter Banu, Junior Specialist (Technical), KGF, for writing the document. I appreciate the contributions of those scientists who were directly and indirectly involved in the research and developmental activities of *Bt* brinjal from 2005 to 2017.

I also acknowledge the contributions of Dr Md. Nazmul Islam, the then Secretary, MoA, and Mr Nazibur Rahman, the then Secretary MoEF, for releasing *Bt* brinjal varieties in Bangladesh during 2013.

Finally, I acknowledge the support of our Hon'ble Prime Minister, Sheikh Hasina and Hon'ble Agriculture Minister, Matia Chowdhury, MP, Government of Bangladesh. Without their vision, continuous encouragement and help, the successful completion of the ABSP II project and release of *Bt* brinjal would not have been possible in Bangladesh.



Rafiqul Islam Mondal, PhD

Former Director General

Bangladesh Agricultural Research Institute
Gazipur, Bangladesh

Acronyms and Abbreviations

ABSP	Agricultural Biotechnology Support Project
APAARI	Asia-Pacific Association of Agricultural Research Institutions
APCoAB	Asia-Pacific Consortium on Agriculture Biotechnology and Bioresources
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BJRI	Bangladesh Jute Research Institute
BRRRI	Bangladesh Rice Research Institute
BBS	Bangladesh Bureau of Statistics
BC	Backcross
BCC	Biosafety Core Committee
BRB	Biosafety Rules of Bangladesh
BSFB	Brinjal Shoot and Fruit Borer
BSO	Biological Safety Officer
<i>Bt</i>	<i>Bacillus thuringiensis</i>
CBD	Convention on Biological Diversity
CDB	Cotton Development Board
CFT	Confined Field Trial
CRISPER	Clustered Regularly Interspaced Short Palindromic Repeat
CSO	Chief Scientific Officer
DAE	Department of Agricultural Extension
DNA	Deoxy-ribo Nucleic Acid
DG	Director General
FAO	Food and Agriculture Organization
FBC	Field level Biosafety Committee
FYP	Five Year Plan
GDP	Gross Domestic Products
GE	Genetic Engineering
GM	Genetically Modified

GR	Golden Rice
GI	Glycemic index
GFP	Green Fluorescent Protein
GMO	Genetically Modified Organism
GSP	Gross Domestic Product
HRC	Horticulture Research Centre
IBC	Institutional Biosafety Committee
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
KGF	Krishi Gobeshona Foundation
LEHRI	Lembang Horticultural Research Institute
LMO	Living Modified Organism
Mahyco	Maharashtra Hybrid Seeds Company
MoA	Ministry of Agriculture
MoEF	Ministry of Environment and Forest
MP	Member of Parliament
MSU	Machigan State University
MT	Metric Ton
MTA	Material Transfer Agreement
NBF	National Biosafety Framework
NCB	National Committee of Biosafety
NSDS	National Sustainable Development Strategy
NTCCB	National Technical Committee on Crop Biotechnology
OFRD	On Farm Research Division
PRSP	Poverty Reduction Strategy Paper
PSO	Principal Scientific Officer
RCFT	Regulatory Confined Field Trial
RDI	Recommended Daily Intake
R&D	Research and Development
RNA	Ribo-Nucleic Acid
SDG	Sustainable Development Goal
TCRC	Tuber Crops Research Centre
UBINIG	Unnayan Bikalper Nitinirdharoni Gobeshona
USAID	United States Agency for International Development

Executive Summary

Brinjal (*Solanum melongena* L.), also known as aubergine and eggplant, is one of the most important vegetables cultivated and consumed in Bangladesh. It is cultivated year-round on approximately 50 thousand hectares of land by 150 thousand farmers. One of the major constraints of brinjal cultivation is the shoot and fruit borer insect which infests young shoot tips and growing fruits, and thus cannot be controlled easily by spraying insecticides. Farmers spray insecticides frequently to control the insect but without much success. To address this problem, BARI started research work on *Bt* brinjal in 2005 with the technical co-operation of Cornell University, under ABSP II with the financial assistance from USAID.

During 2005, two BARI scientists visited the Mahyco Agricultural Research Station, Jalna, Maharashtra, India, with nine brinjal cultivars which were popular in Bangladesh, and these cultivars were hybridized with the candidate brinjal plants containing the *Bt* gene and collected F₁ seeds. Backcrosses (BC₁) were done there and the resultant seeds were brought back to Bangladesh. Then successive backcrosses were made at BARI from 2006 to 2011. Multi-location confined field trials were conducted at seven different locations of BARI. In 2013 after compiling all the results, BARI applied to National Committee of Biosafety (NCB), MoEF following Biosafety Guidelines/Rules of the country through MoA for the approval of four *Bt* brinjal genotypes viz. BARI *Bt* Begun-1, BARI *Bt* Begun-2, BARI *Bt* Begun-3 and BARI *Bt* Begun-4.

Finally, in October 2013, the above four *Bt* brinjal varieties were approved for commercial cultivation. The first *Bt* brinjal seedling distribution program was held on January 22, 2014 at BARC, with the Hon'ble Agriculture Minister, Matia Chowdhury, MP, was present as a Chief Guest. *Bt* brinjal seedlings were distributed among 20 farmers from Gazipur, Pabna, Rangpur and Jamalpur districts. In the following years, the number of farmers cultivating *Bt* brinjal increased, and currently more than 7500 farmers are growing *Bt* brinjal in 2017-18. Bangladeshi *Bt* brinjal samples have also been tested in the internationally recognized Covance laboratory in London also no difference between *Bt* brinjal and its non-*Bt* counterpart was reported. Also, no detrimental effect of *Bt* brinjal was found in the tested animals. *Bt* brinjal varieties are being cultivated since 2014 in Bangladesh, so far no evidence of any unaccepted or undesirable effects that might harm human health, animal, or the environment has been reported.

Now, *Bt* brinjal is a successful crop in Bangladesh. Farmers are very happy with the performance of *Bt* brinjal varieties which were found safe for consumption, increased the profitability of the small holder farmers and reduce the use of toxic pesticides for significant environmental gains.

1 Introduction

1.1 Brief Agricultural Scenario of Bangladesh

Bangladesh is one of the most densely populated countries in the world with more than 160 million people in 147,570 square km² and 1100 people/km². Around 70% of the population in Bangladesh is directly or indirectly involved in agricultural sector. The net cultivable area is 8.52 million ha, out of 14.76 million ha, which reflects 57.72% of the total country's area. The agricultural sector's contribution in Gross Domestic Production (GDP) is 14.77% (2016) and it employs 47% of the total labor forces. The country's cropping intensity is over 192% which is approaching to 200%, average farm size is about 0.68 acre (AIS, 2018) and about 46 economic crops are grown. The farmers are engaged with crops, fisheries and livestock production with a view to utilize available natural resources and improving their livelihood.

Agriculture is the key driver of the growth of Bangladesh's economy as well as food and nutritional security and also directly associated with poverty alleviation, livelihood improvement and employment generation. Government of Bangladesh has a strong commitment to protect and improve the environment and to preserve and safeguard the natural resources, biodiversity, wetlands, forests, fisheries and livestock for agricultural sustainability. With all of these efforts the country achieved self-sufficiency in staple food particularly in rice from its deficit level.

The government's investment in irrigation facilities, rural infrastructure, agricultural research and extension services have helped Bangladeshi farmers to achieve dramatic increases in agricultural production, though agricultural productivity continues to lag far behind in the sub-continent. The process of agricultural production is underpinned by the increasing use of agro-chemicals, irrigation, and multiple cropping. Significant production transformation has been achieved and food production has increased more than four times since the nation's independence in 1971. This has helped to feed the country's growing population, though food security still remains a major development issue in Bangladesh. Rice, wheat, maize, jute, sugarcane, tobacco, oilseeds, pulses and potatoes are the principal crops of Bangladesh. In the past, before the onset of Bangladesh's garment sector, jute was country's main export items. The government is attempting to diversify the economy to avoid heavy reliance on the agriculture sector, which is highly vulnerable to natural disasters, such as cyclones, droughts and floods. To produce enough food to sustain Bangladesh's growing population is a major goal of the agriculture sector. However, Bangladesh still relies on imports to meet domestic

demands especially during the years when production is inadequate. Bangladesh is a major importer of wheat as it is a part of its staple diet, and imports about 3.3 million tons annually. Over the last few years, Bangladesh also imported fresh and dry fruits worth approximately US\$70 million per year as they are very popular amongst Bangladeshi consumers (BBS, 2017).

Bangladesh has made a considerable achievement in the agriculture sector especially in food grain production. Over the last four decades, cereal production has increased from about 10 million MT in the 1970s to 39.68 million MT in 2016-2017, *i.e.* increased more than four times, although arable land decreased from 9.8 million ha to 8.27 million ha (BBS, 2017). It is expected that rice consumption will be 38.62 million MT by 2030. Bangladesh is near to become self-sufficient in cereals production but other crops like pulse, oilseeds, spices, fruits and vegetables are not sufficient to meet the demands. The population pressure remains high as the population is estimated to be increased to 200 million by 2030.

The 7th Five Year Plan (7FYP) and Poverty Reduction Strategy Paper (PRSP) have provided continuity to most of the efforts initiated to achieve the aims and objectives of agricultural development and poverty reduction. Among the declared Sustainable Development Goals (SDGs), end hunger, achieve food security and improve nutrition and promote sustainable agriculture (Goal-2) and take urgent action to combat climate change and its impacts (Goal-13) are the two identified major goals related to the agriculture sector specially the crop sub-sector. Poverty has been showing a declining trend due to the government investment policy in the agriculture sector which stands at 24% in 2017 in against of 40% in 2009. In the National Agriculture Policy 2013, 7FYP and SDGs action plan emphasis has been given on ensuring food safety, innovative improvement for e-agriculture, promoting urban agriculture and homestead gardening, roof top agriculture, hydroponic agriculture, yield gap minimization, expansion of irrigation facilities and farm mechanization, quality seed production and distribution, supply of quality inputs, quality horticultural crop production and popularization of good agricultural and Integrated Pest Management (IPM) practices (MoA, 2016-17). The National Sustainable Development Strategy (NSDS) has suggested combating the environmental challenges impeding the development. NSDS fulfills Bangladesh's commitment to the international community to formulate and implement a sustainable development strategy addressing environmental issues. Adoption of IPM technology in agricultural production by mass people is also a good example regarding environmental sustainability (Alam *et al*, 2003). The highest importance is given on agricultural research for developing crop varieties for stress-prone areas with shorter maturity, identification of technologies for promoting cultivation of nutritious varieties with high yield, strengthening research for developing non-rice crops, increasing cropping intensity and use of frontier sciences like biotechnology.

The major focus of the SDGs action plan and 7FYP in the sector will be very important for consolidating and expanding the productivity gains already achieved in food grain production as well as developing the policies, strategies and actions to accelerate the crop diversification, crop intensification and commercialization process by increasing local and export market opportunities for the farmers and other stakeholders. Further attention will have to be given to reduce knowledge gaps as a means to sustain production and to deal with emerging issues arising out of globalization and trade. The development vision of agricultural research is to generate demand-led green and climate-smart technologies/information suitable for highly productive and value-added intensive agriculture.

1.2 Area, Production and Productivity of Vegetable Crops in Bangladesh

Any herbaceous plant whose fruits, seeds, roots, tubers, bulbs, leaves *etc.* are used as food is a vegetable. Nearly 100 different types of vegetable comprising both local and exotic types are grown in Bangladesh. Vegetables are very important for nutritional, financial, and food security in Bangladesh (Table 1). However, the availability of vegetables is only about 1/5 of the recommended requirement of 220 g/person/day (FAO, 2013).

The area under vegetable farming has increased and the production of vegetables is also increased. However, summer vegetable cultivation is constrained by adverse climate and pest attacks. The major winter vegetables are cabbage, cauliflower, tomato, brinjal, radish, hyacinth bean, bottle gourd, spinach *etc* (Fig. 1). The area and production difference has been narrowed down in the last couple of years due to the intervention of modern technologies and increase of awareness (Fig. 2). It is also observed that export trend of vegetables has consistently increased in Bangladesh (Fig. 3). Among the winter vegetables tomato, bottle gourd and brinjal cover 13%, 14%, 15% of area

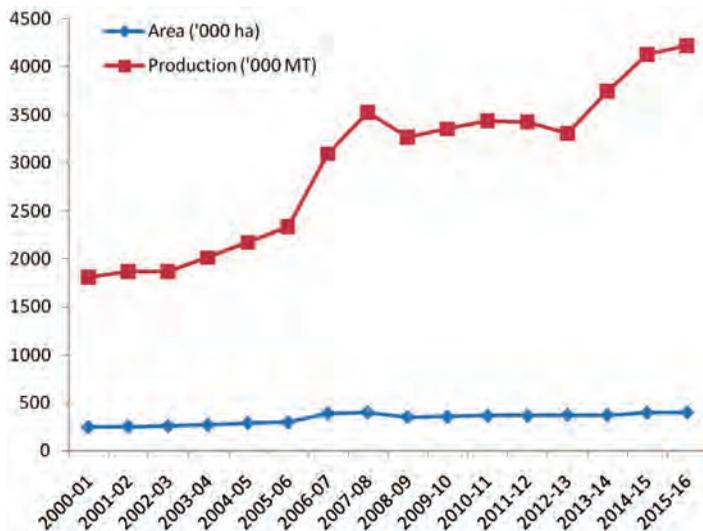
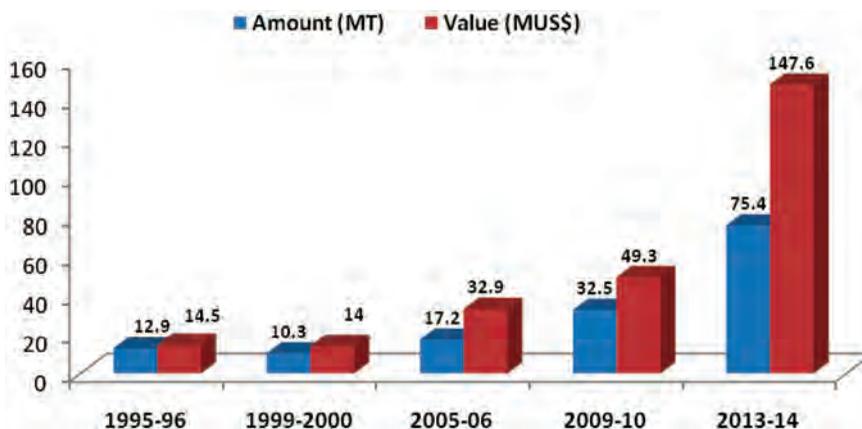


Fig. 1. Common vegetables cultivated in Bangladesh

(Fig. 4) and 10%, 15%, 16% of production (Fig. 5). While major summer vegetables are pumpkin, bitter gourd, teale gourd, ribbed gourd, ash gourd, okra, yard-long bean, and Indian spinach among others (Figs. 6, 7). Some vegetables like brinjal,

Table 1. Status of vegetables in Bangladesh

Area	0.4 m ha
Production	3.73 m MT (BBS, 2017)
Present consumption	62 g/day/person (BBS, 2017) 125 g/day/person (FAO, 2013)
Recommendation	220 g/day/person (FAO, 2013)
Requirement (to meet the recommended amount)	13.25 million MT
Production to be increased (to meet the recommended amount)	More than 3 times of the present production
No. of cultivated vegetable crops	>90

**Fig. 2.** Area and production trend of vegetables in Bangladesh**Fig. 3.** Export trend of vegetables in Bangladesh during 1995 to 2014

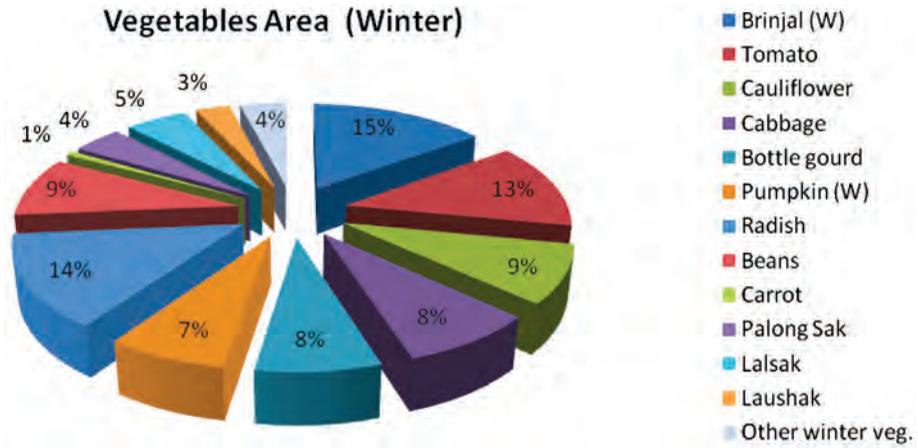


Fig. 4. Area (%) of different vegetables grown in Bangladesh during the winter season

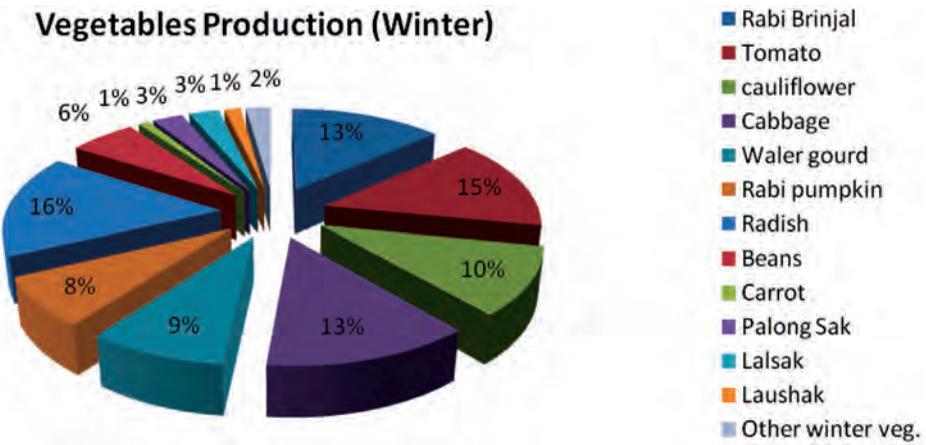


Fig. 5. Production (%) of different vegetables grown in Bangladesh during the winter season

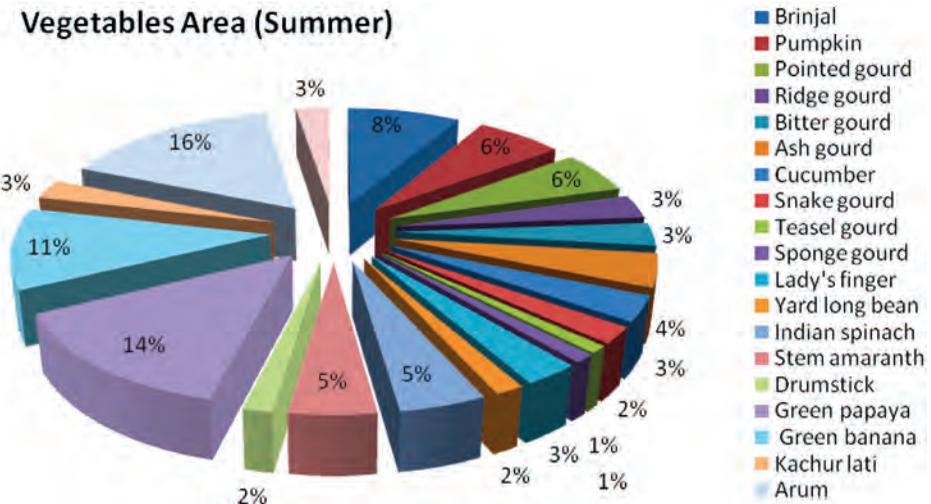


Fig. 6. Area (%) of different vegetables grown in Bangladesh during the summer season

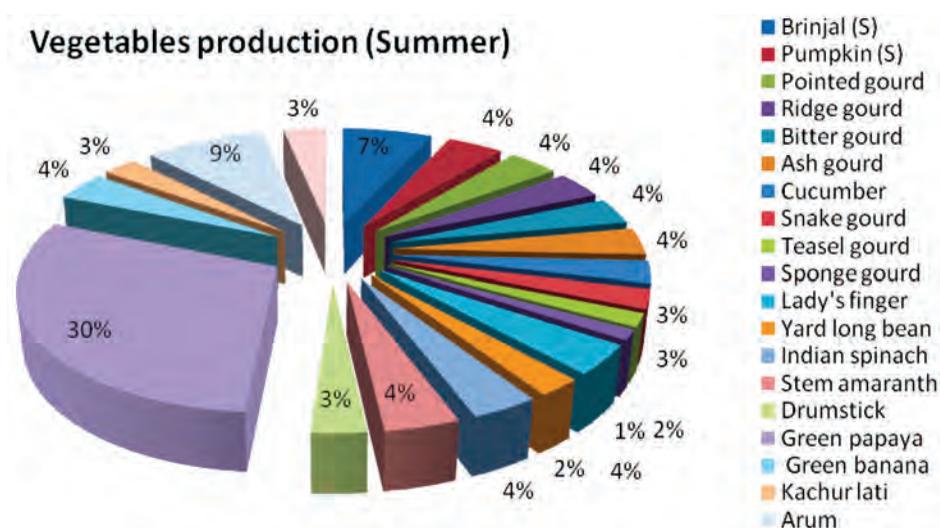


Fig. 7. Production (%) of different vegetables grown in Bangladesh during the summer season

pumpkin, bitter gourd, cucumber and red amaranth grow in both winter and summer seasons.

1.3 Production System of Vegetables

Vegetable farming in Bangladesh can be grouped into 3 categories based on the scale of production and objectives of farming:

1.3.1 Vegetable Production on Homestead

Vegetables differing in morphology, growth habit, light, and nutrient requirements are grown on the homestead under a complex multiple cropping system. Traditionally, farm families grow vegetables using local varieties and indigenous technologies mainly for family consumption and sell their surplus production. Women play the dominant role in this system.

1.3.2 Vegetable Production for Commercial Market

Commercial production in field plots combine improved and indigenous technologies under irrigated and rainfed conditions. In this system, use of the high yielding varieties/hybrids, close planting, multiple cropping, efficient nutritive and field management along with proper marketing management are practiced. Some vegetables are produced in localized areas because of the favorable agro-ecological conditions, and better marketing infrastructure. Pointed gourd in Bogra, onion in Faridpur, hyacinth bean in Chittagong, early cauliflower in Tangail and tomato in Jessore and Nawabganj are some of the examples of concentrated zones. Now-a-days, vegetables like bottle gourd, yard-long bean, okra, teasle gourd and French bean are being grown for the export market on a limited scale.

1.3.3 Vegetable Farming for Seed Production

The annual requirement of vegetable seed is about 3000 MT. Unavailability of good quality seeds of improved varieties is a major constraint in vegetable production. Only about 4% of the total requirement of vegetable seeds is supplied by the public sector, 10% are imported, and the remaining demand is met through farmer to farmer exchanges, and local seed companies.

1.4 Important Insect-Pest and Diseases of Some Vegetables

Insect-pest and diseases infestation varies from crop to crop. Some major insect and disease infestation of various vegetable crops are mentioned in Table 2.

Table 2. Major insect-pest of some common vegetables grown in Bangladesh

Family	Name of vegetable	Name of insect-pest
Brassicaceae	(Cabbage, cauliflower, knolkhol, lettuce, radish, etc.)	Caterpillar, <i>Spodoptera litura</i> <i>Lepidoptera</i> , <i>Noctuidae</i>
Solanaceae	Brinjal, tomato, potato	Shoot and fruit borer, red mite, epilachna beetle, aphid, fruit borer, potato tuber moth
Fabaceae	Hyacinth, pea, string bean, winged bean, sword bean, lima bean	Flower bud and pod borers, <i>Maruca testulalis</i> , <i>Euchrysops cnejus</i> , <i>Heliothis armigera</i>
Cucurbitaceae	Gourd, cucumber	Melon fruit fly, pumpkin beetle

Table 3. Major diseases of brinjal, potato and tomato in Bangladesh

Crop	Disease	Pathogen
Brinjal	Bacterial wilt	<i>Ralstonia solanacearum</i>
	Fusarium wilt	<i>Fusarium oxysporum</i>
	Leaf spot	<i>Alternaria</i> spp., <i>Cercospora</i> spp.
	Damping off	<i>Fusarium</i> spp., <i>Pythium</i> sp., <i>Sclerotium rolfsii</i>
	Phomopsis blight	<i>Phomopsis vexans</i>
	Little leaf	Mycoplasma
	Foot rot and collar rot	<i>Sclerotium rolfsii</i>
	Root knot	<i>Meloidogyne incognita</i> , <i>M. javonica</i>
Potato	Late blight	<i>Phytophthora infestans</i>
	Stem canker & black scurf	<i>Rhizoctonia solani</i>
	Bacterial wilt	<i>Ralstonia solanacearum</i>
	Soft rot	<i>Erwinia carotovora</i>
	Common scab	<i>Streptomyces scabies</i>
	PLRV (Potato leaf roll virus)	Virus
	Mosaic (Potato virus Y)	Virus
	Dry rot	<i>Fusarium caerulum</i>

Crop	Disease	Pathogen
Tomato	Late blight	<i>Phytophthora infestans</i>
	Early blight	<i>Alternaria solani</i>
	Bacterial wilt	<i>Ralstonia solanacearum</i>
	Fusarium wilt	<i>Fusarium oxysporum</i>
	Tomato yellow leaf curl virus (TYLCV)	Virus
	Damping off	<i>Fusarium</i> spp., <i>Pythium</i> sp., <i>Sclerotium rolfsii</i>
	Blossom end rot	Physiological

1.5 Brinjal as Vegetable Crop in Bangladesh

Solanum melongena L., popularly known as brinjal or eggplant or aubergine, belongs to the family *Solanaceae* and is a widely grown vegetable in Asia, parts of Europe and Africa. Brinjal has been cultivated in Bangladesh for the last 4,000 years, although it is often thought of as a Mediterranean or mid-eastern vegetable.

The area under brinjal cultivation in Bangladesh is estimated of 50.42 thousand ha (Fig. 8) with total production of 504.81 thousand MT (Fig. 9) and yield 10.0 MT/ha (Fig. 10) in 2015-16. The brinjal production of Bangladesh is only 1.1% of the

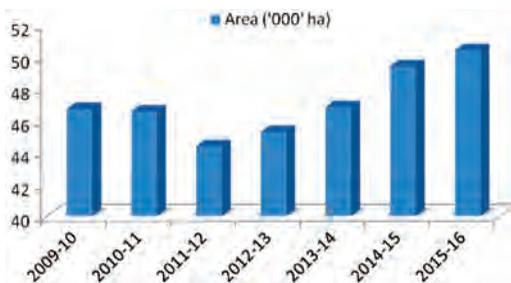


Fig. 8. Area of brinjal in Bangladesh

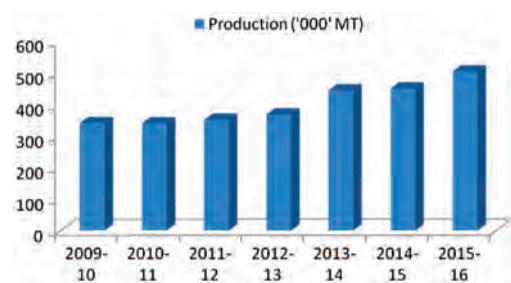


Fig. 9. Production of brinjal in Bangladesh

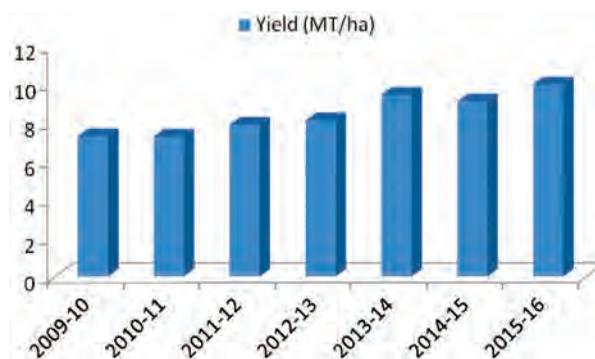


Fig. 10. Yield of brinjal in Bangladesh

total global production. The area, production and yield have increased over the past few years. Brinjal is grown by smallholder farmers and is an important source of income. It is a versatile crop, adapted to different agro-climatic regions and can be grown throughout the year. There is a wide range of consumer preference in the country dependent upon fruit colour, size and shape, thereby a number of cultivars are grown. Brinjal is a highly productive crop, the fruits are consumed as cooked vegetables in various ways, and dried shoots are used as fuel in rural areas of Bangladesh.

1.5.1 Nutritional Composition of Brinjal

Brinjal is a good source of minerals and vitamins and is rich in total water soluble sugars, free reducing sugars, amide proteins among other nutrients and antioxidants as well. Brinjal is a very nutritive vegetable. In 100 g of edible portion of brinjal contains 52.0 mg of chlorine, 47.0 mg of phosphorus, 44.0 mg of sulphur, 6.4 mg of vitamin A and other nutrients also (Table 4).

1.5.2 Nature of Damage by the Brinjal Shoot and Fruit Borer

A primary factor that adversely affects brinjal yield is the Lepidoptera pest *Leucinodes orbonalis*, also called the brinjal shoot and fruit borer (BSFB). Within one hour after hatching, the BSFB larva bores into the nearest tender shoot, flower, or fruit. Soon after boring into shoots or fruits, it plugs the entrance hole with excreta. In young plants, caterpillars are reported to bore inside petioles and midribs of large leaves. As a result, the affected leaves may drop off (Tewari and Sardine, 1987). Larval feeding inside the shoots results in wilting of the young shoot. The presence of wilted shoots in a brinjal field is the surest sign of damage by this pest. The

Table 4. Nutritive value of 100 g of edible portion of brinjal fruits

S. No.	Nutrient	Content	S. No.	Nutrient	Content
1.	Moisture	92.70%	11.	Carbohydrates	4.00%
2.	Calcium	18.0 mg	12.	Copper	0.17 mg
3.	Energy	24 K cal	13.	Vitamin A	6.4 mg
4.	Magnesium	16.0 mg	14.	Potassium	2.0 mg
5.	Fibre	1.3 g	15.	Vitamin B	0.15 mg
6.	Phosphorus	47.0 mg	16.	Sulphur	44.0 mg
7.	Fat	0.3 g	17.	Vitamin C	12.0 mg
8.	Iron	0.9 mg	18.	Chlorine	52.0 mg
9.	Protein	1.4 g	19.	Oxalic acid	18.0 mg
10.	Sodium	3.0 mg	20.	β-carotene	0.74 μg

Source: Choudhary & Gaur (2009)

damaged shoots ultimately wither and drop off. This reduces plant growth, which in turn, reduces fruit number and size. New shoots can arise but this delays crop maturity and the newly formed shoots are also subject to larval damage. Larval feeding in flowers - a relatively rare occurrence - results in failure to form fruit from damaged flowers. Larval feeding inside the fruit results in destruction of fruit tissue. This makes even slightly damaged fruits unfit for marketing. The yield loss varies from season to season and from location to location. Damage to the fruits particularly in autumn, is very severe and the whole crop can be destroyed. Besides a considerable reduction in crop yield, the fruits that show infestation are either entirely discarded or command a vastly diminished market value.

1.5.3 Losses

As a preventive measure against BSFB, farmers use large quantities of chemical insecticides either singly or as toxic cocktails to get blemish free fruit. Attempts in using biological control to prevent pest infestation have not been successful. The frequency of insecticide application is as much as 80 times, the prescribed limit and despite these intensive precautionary insecticide sprays, farmers lose any where between 30 to 60% of the crop yield due to BSFB pest and also incur considerable expenditure due to the high costs of the insecticides. The shoot and fruit damage caused by this pest starts soon after transplantation and continues until the last harvest. Due to repetitive pesticide sprays during a single cropping season, farmers suffer from debilitating health problems resulting from direct exposure to these insecticides. These chemical cocktails not only pose a serious health hazard to the farmers, but also destroy beneficial predatory insects and parasitoids that help to control the BSFB pest. Furthermore, BSFB have, in recent years, developed resistance to many of these pesticides thus rendering the sprays only partially effective. Insecticide residues from such intensive spraying remains on the marketable fruit and poses severe health hazard to consumers. BSFB poses a serious threat because of its high reproductive potential and rapid turnover of generation.

2 Agricultural Biotechnology in Bangladesh

Biotechnology is the application of any technology to biological systems and living organisms or derivatives to develop or make useful products for specific use. Bangladesh, being an agricultural country, biotechnological application in this area has received adequate attention. Tissue culture, embryo grafting, somaclonal variation, micropropagation, etc. of various types of economically important plants are being pursued in universities and research organizations. The programme on plant biotechnology in Bangladesh was initiated in late 1970s in the Department of Botany, Dhaka University, with tissue culture of jute. Thereafter, within a span of 10-12 years tissue culture research laboratories have developed in different universities and R&D organizations. As a result of intensive work on plant tissue culture protocols on plant regeneration and micropropagation have been developed for different crops, forest plants, ornamental and fruit trees as well as vegetables. Besides these, researches on transgenic plant development and production of high yielding and pest/insect resistant varieties through genetic engineering, and biochemical study programmes of some key crop plants have also been initiated at some laboratories of research institutes and universities of Bangladesh.

2.1 Late Blight Resistant Potato

Potato is now an important crop in Bangladesh. One of the main problems of potato cultivation is its susceptibility to the late blight disease caused by *Phytophthora infestans*. The RB gene was identified in the wild diploid potato species *Solanum bulbocastanum* and introduced into cultivated late blight (*Phytophthora infestans*) susceptible potato variety Katahdin (*Solanum tuberosum*) at Wisconsin University, USA, using biotechnological approaches. In Bangladesh, most of the potato varieties are very susceptible to late blight. Among the varieties Cardinal and Diamant are very popular and thus these two varieties were introgressed with the RB gene from two RB hybrid clones (SP951 and SP904) following conventional breeding (hybridization) and transformation (molecular breeding). The hybridization was done in 2006 at Lembang Horticultural Research Institute, Lembang, Indonesia (LEHRI) and transformation was done in 2007 at the Wisconsin University, USA (ABSP II, 2007). Confined Field Trial (CFT) was conducted under BARI at different locations during 2007 to 2014 and Regulatory Confined Field Trials (RCFT) were conducted in 2014-15. The improved micro-tubers and *in vitro* plantlets will be multiplied and screened

against late blight and subsequently crossed and backcrossed with promising and high yielding varieties of Bangladesh. Besides this, a new project on 3 R genes is launched and contained trial will be carried out with effect from June 2018. In 2015, USAID has awarded US\$ 6 million project to the Michigan State University (MSU) to intensify the development of LBR potato in Bangladesh under the Feed the Future Biotechnology Partnership Project – the US Government Global Hunger and Food Security Initiatives (MSU, 2015). From 2016, MSU started to work with BARI to develop late blight resistant potato in Bangladesh under the MoU signed between BARC and MSU in 2017.

2.2 Golden Rice

Rice does not contain any beta carotene. Dependence on rice as the predominant food source, therefore, necessarily leads to vitamin A deficiency, most severely affecting small children and pregnant women. Consumption of only 150 g of Golden Rice a day is expected to supply half of the recommended daily intake of vitamin A for an adult. People in Bangladesh depend on rice for 70% of their daily calorie intakes. First generation Golden Rice (known as GR-1) was developed through infusing a gene from daffodil but later the second generation variety, known as GR-2, has been developed by taking a gene from corn as it gave much better output of pro-vitamin A. The Plant Breeding Division of Bangladesh Rice Research Institute (BRRI), Gazipur, conducting multiple trials of Golden Rice, BRRI Dhan 29 in different locations of the country (BRRI, 2017).

2.3 Salt Tolerant Rice

With green house support of the Biotechnology Division of BRRI, the Department of Biochemistry and Molecular Biology of University of Dhaka have been screening some of the salt tolerant transgenic rice lines. BRRI's Annual Report 2016-17 reported seedling tests for 14 transgenic lines of rice variety BRRI Dhan 28, 29, 36 and 2 BRRI Dhan 47 containing Pea DNA Helicase 45 (PDH45). Of those, five lines were found to be salt tolerant at the seedling stage and were selected for reproductive stage characterization at 10 dSm⁻¹ and for assessing yield potential under stress (BRRI, 2017).

2.4 *Bt* Cotton

To develop a GM cotton variety for commercial release, the Cotton Development Board (CDB) has initiated collaborative research with foreign cotton seed producing companies. CDB applied for approval to import seed and conduct research jointly with India. An approval for contained trial was given to test productivity and stability of four hybrid *Bt* cotton varieties having X-GENE, Cry1Ac Truncated (Event-1). The goal is to develop an efficient GM cotton variety which is resistant to bollworm and Spodoptera/army worm (CDB, 2017).

2.5 Genome Sequence of Jute

Bangladesh has made use of genome sequencing technology to sequence the jute blight, root rot and charcoal rot of more than 500 crops and non-crop species including jute. While the jute genome project earned Bangladesh the pride of being the first ever country to sequence the whole genome of jute, the discovery of the genome of the deadly fungi (*Macrophomina phaseolina*) later will definitely have an impact on the improvement of yield and quality of the jute fibre. The jute genome project was carried out through a tripartite combination of the public-private-government partnership of the three institutions: University of Dhaka, IT farm Datasoft and Bangladesh Jute Research Institute (BJRI), Dhaka, the declaration of their discovery came out on June 16, 2010 by Prime Minister Sheikh, Hasina in an assembly of the national parliament. In consequence, the Agriculture Ministry took an initiative with a project entitled “Basic and Applied Research on Jute (BARJ)” at BJRI, which brought about another breakthrough in September 2012, with the discovery of the entire genome of the dangerous fungus, *Macrophomina phaseolina*. Dr Maqsdul Alam, Professor of Microbiology, Hawaii University, led the teams for both the projects. These two innovations will hopefully help to bring back the golden days of jute, the once known as ‘golden fibre’ (BJRI, 2017).

2.6 Bt Chickpea

Chickpea has the pod borer problem, which is causing as much as 48% yield loss. Similar to the brinjal, a pod borer resistant *Bt* chickpea was developed by the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India, in the hope of reducing the damage of intensive use of pesticide to the environment. BARI has also started research on the *Bt* chickpea.

2.7 Other Crops

Research on the development of virus resistant tomato and salt tolerant wheat are going on at Biotechnology Division of BARI. The Plant Breeding Division of BRRI is also working with the International Rice Research Institute (IRRI) to develop zinc (Zn) and iron (Fe) enriched transgenic rice variety, for which the NCB has already approved the importation of seed for trials. The Biotechnology Division of BRRI is also doing research on the development of non-transgenic low glycemic index (GI) rice variety, a salt-tolerant rice variety, and an antioxidant-enriched black rice variety. The plant breeding and biotechnology laboratory of the Department of Botany, University of Dhaka, has been working since 2009 to develop a peanut (*Arachis hypogaea* L.) resistant to fungal disease. Transformation experiments in two varieties of peanut, namely, Dhaka-1 and BINA Chinabadam-4, were performed using the *Agrobacterium* strains LBA4404 containing the antifungal protein gene (AFP) and the marker gene Neomycin phosphotransferase II (NPTII). Transformation frequency

was 0.85% and 0.69% in Dhaka-1 and BINA Chinabadam-4 variety, respectively. The integration of a fungal-disease-resistant gene within the genomic DNA was confirmed through PCR analysis followed by Southern blot. T2 seeds were collected and further molecular analysis of these transgenic plants will be carried out.

2.8 Development of Genetically Modified Brinjal

Brinjal is an important vegetable in Bangladesh grown all over the country throughout the year. It is the second most important vegetable (after potato) in terms of acreage and production, and plays a significant role in Bangladeshis' daily diet, livelihood and farm income. The crop is damaged severely by the notorious insect called BSFB and the damage due to this insect ranges from 30-70% depending upon the locality and edaphic conditions (Teweri and Sardana,1987). BSFB is only vulnerable to sprays for a few hours before it bores into the plant, forcing farmers to spray insecticides as often as every 2-3 days. The unrestrained spraying of chemical pesticides adversely affects the health of farm workers. Moreover, pesticide residues from such concentrated use tend to remain for longer periods on vegetable, ultimately affecting consumers' health. Conventional breeding efforts in brinjal breeding have not fructified to develop any commercial brinjal variety or hybrid that is resistant to BSFB. *Bt* brinjal is a genetically modified brinjal, carrying an additional gene that provides an in-built insect protection against BSFB. The development of *Bt* brinjal involves the introduction of the *cry1Ac* gene, expressing an insecticidal protein that confers resistance against BSFB. The *cry1Ac* gene is sourced from environment friendly and ubiquitous soil bacterium called *Bacillus thuringiensis* (*Bt*), which has been frequently used as a biological control measure in granular or powder form to control BSFB and other insect-pests for many years.

Bt brinjal Event EE-1 containing the *cry1Ac* gene has been developed at Mahyco, India, and has undergone a considerable safety assessment in accredited laboratories to ascertain its toxicity and allergenicity. This also contains a gene sequence encoding insecticidal protein in all parts of brinjal plant throughout its life. BARI has started transgenic studies since 2005 through the introgression of the *cry1Ac* gene into nine brinjal varieties from Bangladesh. *Bt* brinjal was tested under contained, confined and open field conditions for 7 consecutive seasons. On completion of all the biosafety studies on *Bt* brinjal, National Committee on Biosafety of the MoEF, which is the apex regulatory body, empowered to accord the commercial approval of GE crops in Bangladesh. The government issued a notification for official release of four varieties of *Bt* brinjal for limited cultivation in the country on October 30, 2013 (ABSP-II, 2014). The performance is quite satisfactory so far and lot of awareness and interest has generated among the farmers.

2.9 Conceptualization of Research Project ABSP-II

A MoU between BARC, Bangladesh and College of Agriculture and Life Sciences of Cornell University, Ithaca, NY, USA was signed on June 27, 2004 in order to facilitate international academic exchange to develop academic and scientific relationship and to support of collaborative research activities. Cornell University was engaged in managing the consortium based, USAID funded the ABSP-II that aimed at delivering bio-engineered products and technologies to targeted countries, including Bangladesh. The initial duration of the project was 5 years, commencing from October 2005. The collaborating institutions recognize that there is considerable benefit that would accrue to Bangladesh on account of ABSP-II initiatives. ABSP-II facilitate technology access and provide research support in the biotechnological area, higher training and study visit for Bangladeshi scientists. This MoU covered the areas of other activities of Cornell University in Bangladesh.

BARI started research work on biotechnological aspect to develop GM brinjal varieties resistant to BSFB, and late blight resistant potato varieties (ABSP-II, 2007-2014). Technical support was provided by the Cornell University and financial support by USAID. Under this project, a number of scientists, administrators and policy makers were trained and visited some biotechnology research centres in India, USA and other countries. After expired of the MoU, collaboration was extended further and Cornell University worked with BARI up to 2016.

Another separate letter of agreement was signed with BARI and Mahyco Seed Company of India to work on ABSP-II. Cornell University was directly involved from the beginning of the project and coordinated up to 2016. Finally, nine *Bt* brinjal varieties were developed. Out of nine varieties, four were released for commercial cultivation, three varieties were proposed for approval and two varieties are under further study.

2.10 Research Initiatives at BARI

In 2005, BARI created a multidisciplinary team comprised of biotechnologist, plant breeder, soil scientist, plant pathologist and entomologist under ABSP-II Project. Multi-location confined field trials were conducted in seven research stations of BARI (Joydebpur, Jamalpur, Jessore, Hathazari, Barisal, Ishurdi and Rangpur) from 2008-2013 with the permission of the MoEF and MoA and approval of NCB following the biosafety rules. The goal was to increase food security and improve environmental quality through supporting the national partners in their efforts to commercialize and adopt genetically engineered eggplant. Every year to conduct any experiment on *Bt* brinjal, prior approval was needed by the MoEF as per biosafety guidelines.

3 Regulatory Process in Bangladesh

The economic potential of this new biotechnology in agriculture, health, energy and environment is well recognized. However, there are concerns that the GMOs may pose risk to humanity and environment and mixing genes from unrelated organisms might create natural imbalance that is not yet clearly understood. There are also fears that manipulated genes or products thereof, if allowed to move freely in nature, may pose potential hazards and also that certain transgenic organisms may be harmful or become harmful to economic plants, animals and human being.

To address the issues of public and environmental safety concerning modern biotechnology, its product or application and above all to discharge the obligations of the Convention of Biological Diversity and the Cartagena Protocol, there was an urgent need to develop biosafety guidelines to regulate laboratory research, field studies and commercial release of GMOs and products thereof. Many research institutes in the country are engaged in modern biotechnological research. Skilled manpower is available for this purpose within the country. However, for collaborative projects with international research institutes, proposals were pending due to lack of proper biosafety guidelines. The government also recognized the importance of biotechnological research in national development by establishing the National Institute of Biotechnology. Adoption of biosafety guidelines was essential for all organizations working on modern biotechnology and genetic engineering so as to safely handle, store and transfer the GMOs and products thereof for human benefit and earn international recognition for such work (MoEF, 2007).

3.1 Biosafety Guidelines in Bangladesh (MoEF, 2007)

Biosafety is used to describe the policies and procedures adopted to ensure the environmentally safe application of modern biotechnology. It is a term that is gaining wider currency as more countries benefit from the application of modern biotechnology in medicine, agriculture, fisheries and livestock, and in the environmental management, without endangering public health or environmental safety. It is noteworthy to mention that Biosafety Guidelines in Bangladesh was first formulated by the Ministry of Science and Technology in 1999 when Cartagena Protocol on Biosafety to the Convention on Biological Diversity was not in place. Bangladesh ratified the Protocol in 2004. Considering the obligation of the Protocol, the guidelines have been updated by the MoEF (2007), in accordance with the latest information. During update of the guidelines, MoEF has also taken National Policy on Biotechnology into consideration and recasted various aspects of Risk

Assessment and Risk Management in the light of Cartagena Protocol (Gupta *et al*, 2014).

Biosafety guidelines are applicable to all research and development activities of modern biotechnology conducted in laboratories of the government research institutes, state enterprises, universities, international organizations, private companies or non-governmental organizations located in Bangladesh. It applies to laboratory and field trial, trans-boundary movement, transit, handling and use of all GMOs/LMOs that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health.

In accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development, the objective of these guidelines is to contribute to ensuring an adequate level of protection in the laboratory, field trial, safe transfer, handling, use and transboundary movement of GMOs/LMOs as part of modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human and animal health. On the basis of the precautionary principle, the guidelines provide a framework for the following aspects:

- a. Develop acts, rules, standards and scientific database, codes of practice and monitoring capabilities and enforcement manuals for assessing risk in the research and development and release of GMOs/LMOs into the environment.
- b. Provide the basis to ensure safety of the developers and end-users of modern biotechnological products.
- c. Promote the development and enforcement of regulations in harmony with national priorities and international approaches.
- d. Foster a favourable climate for developing and accelerating innovation and for adopting sustainable biotechnology products and processes.

The Biosafety Guidelines of Bangladesh cover aspects of risk assessment and safety requirements needed for undertaking: (a) Laboratory work, (b) Field trial and (c) Commercial use, involving (i) Microorganisms (ii) plants, and (iii) Animals.

Guidelines for laboratory work specify the experiments to be categorized as belonging to different biosafety levels like work bearing minimal risk, work bearing low risk, work bearing considerable risk and work bearing high risk and what precautionary measures should be taken to avert such risk.

3.1.1 Biosafety Committees

The MoEF, being the competent national authority and national focal point to implement Cartagena Protocol on Biosafety to the CBD, established a NCB in

order to ensure environmentally safe management of modern biotechnological development including research and development, introduction, use and trans-boundary movement of GMOs/LMOs. A Biosafety Core Committee (BCC) is working to assist and accelerate the functions of NCB. In order to ensure safe management of biosafety activities in the laboratories and in the field there are committees under NCB, such as Institutional Biosafety Committee (IBC), Field Level Biosafety Committee (FBC) and also there are designated Biological Safety Officers (BSO) in each research establishment of the country. Each Committee has separate functions and responsibilities.

3.1.2 National Committee on Biosafety (NCB)

The NCB is composed of the following members

Chairperson

1. The Secretary, Ministry of Environment and Forest (MoEF)
2. Full time Member Secretary to be nominated by MoEF

Members

3. Secretary, Ministry of Science, Information and Communication Technology
4. Secretary, Ministry of Agriculture
5. Secretary, Ministry of Fisheries and Livestock
6. Secretary, Ministry of Health
7. Executive Chairman, Bangladesh Agricultural Research Council
8. Member (relevant), National Board of Revenue
9. Director General, Directorate of Food
10. Director General, Department of Environment
11. Chairman, Bangladesh Atomic Energy Commission
12. Director General, Fisheries Research Institute
13. Director General, Bangladesh Livestock Research Institute
14. Director General, Bangladesh Agriculture Research Institute
15. Director General, Bangladesh Rice Research Institute
16. Director General, Bangladesh Jute Research Institute
17. Director, Bangladesh Forest Research Institute
18. Director General, Bangladesh Institute for Nuclear Agriculture
19. Director, National Institute of Biotechnology
20. One representative from NGO working with environment related issues (to be nominated by NGO affairs bureau).

21. One representative from NGO working with legal aspects related to environment (to be nominated by affairs NGO bureau).

Other biosafety committees at different levels have specific functions to ensure the safety of human being, plants, animals, fisheries and other organisms.

3.2 National Biosafety Framework (2006)

The National Biosafety Framework (NBF) provides the basis for future regulation for the management of biotechnology products in Bangladesh. The objectives of the NBF are two-fold – provide oversight of the existing systems, and identification of future needs for an effective and transparent legislation and administrative system.

The NBF provides the basis for future regulation of the management of GMOs in Bangladesh. The NBF consists of the following elements: (1) National Policy and Guidelines Biosafety, (2) Legal Regime, (3) Administrative System, (4) Monitoring and Enforcement Systems, and (5) Public Participation, Education and Awareness procedures.

3.3 Biosafety Rules of Bangladesh

The Rules are the key legal document that regulates development, import, export, use, and movement of all GMO products. The law provides for punitive measures against misuse of GMO products. The Biosafety Guidelines of Bangladesh are legally binding under the Biosafety Rules. The MoEF is the national authority to enforce the Biosafety Rules. These rules are applicable to the GMOs, micro-organisms and cells and correspondingly to any substances and products and food stuffs, *etc.* of which such cells, organisms or tissues thereof form part. These rules shall also be applicable in the following specific cases; of sale, export, production and all work involved in the field trial of GM plants, animals (including fisheries, poultry, animal and marine life), micro-organisms and cells (Gupta *et al*, 2014).

4 Releasing Process of *Bt* Brinjal in Bangladesh

Firstly, the IBC of BARI took decision to send the four *Bt* brinjal varieties out of nine varieties to National Technical Committee of Crop Biotechnology (NTCCB) of MoA for approval of commercial cultivation. Then the prescribed format for the application was collected from the MoEF and filled up the following information in a prescribed format.

- Title of the project;
- Name and address chief investigator;
- Objective of the project;
- Date and commencement;
- Intended date of completion;
- Location of release with the area to be covered;
- Time of release (Date);
- Expected date of completion of release;
- Information on similar release elsewhere with adverse observations;
- Experimental detail with quantity of materials to be released;
- Is future field release of the same materials expected? If yes then amount, time, location and period of release.
- What is the intended output of the field release?
- Precautionary measures to be taken as per biosafety guideline in case of adverse situations;
- Additional information if needed.

After filling up the format with the above information with adequate documents, the application was sent to NTCCB of MoA, headed by the Secretary, MoA. The NTCCB sent the application to the Biosafety Core Committee (BCC) of the MoA which is headed by the Executive Chairman, BARC. With the recommendation of BCC, the NTCCB sent the application to the MoEF.

After evaluation of the application and verification of all the information and documents, the MoEF approved four *Bt* brinjal varieties for cultivation in Bangladesh. Upon proper assessment by NCB, headed by the Secretary MoEF, and based on the recommendation of the BCC, Government of Bangladesh approved the deregulation of four *Bt* brinjal varieties on October 30, 2013, in Bangladesh in accordance with the existing rules of the country. The four varieties were – 1. BARI *Bt* Begun-1 (Uttara); 2. BARI *Bt* Begun-2 (Kazla); 3. BARI *Bt* Begun-3 (Nayantara); and 4. BARI *Bt* Begun-4 (ISD 006).

4.1 Regulatory Clearance of *Bt* brinjal – An Experience

Following the biosafety guidelines when BARI applied for approval to the MoA and MoEF a number of newspapers published the news heading that BARI applied for approval of *Bt* brinjal. Some of those news headings were positive but some of those were anti-GMO. At that time one NGO, namely Unnayan Bikalper Nitinirdharoni Gobeshona (UBINIG) along with 3 or 4 small NGOs, working in Bangladesh filed a writ petition to the High Court Division of Bangladesh Supreme Court for a moratorium not to release *Bt* brinjal in Bangladesh, on the baseless ground that it is harmful to human health. After arguments from both the sides the Hon'ble Judge asked for research findings whether GMO is harmful or not. On the basis of the science-based evidence, the Hon'ble Judge did not approve moratorium on the release *Bt* brinjal. The Hon'ble Judge suggested BARI to test *Bt* brinjal in a reputed laboratory of the world in the United Kingdom. Accordingly, BARI sent *Bt* brinjal samples to the Covance Laboratory of United Kingdom. After 6 months, BARI received test report which showed that there was no harmful effect of *Bt* brinjal for human health.

These NGOs and some media persons also tried to published the news that the *Bt* gene did not working in *Bt* brinjal. They tried to convince some farmers against the *Bt* brinjal but to no avail. Now it is fifth year of cultivation of *Bt* brinjal by farmers in Bangladesh after its release. Now-a-days there is no negative news at all on *Bt* brinjal in the media.

4.2. Controversy over GMOs

There is controversy over GMOs, especially with regard to their use in producing food. The dispute involves buyers, biotechnology companies, governmental regulators, non-governmental organizations, and scientists. The key areas of controversy about GM food are – labelling, the role of government regulators, the effect of GM crops on health and the environment, the effect on pesticide resistance, the impact of GM crops for farmers, and the role of GM crops in feeding the world population. In 2014, sales of products that had been labeled as non-GMO grew 30% to \$1.1 billion.

There is a scientific consensus that currently available food derived from GM crops poses no greater risk to human health than conventional food, but that each GM food needs to be tested on a case-by-case basis before introduction. Nonetheless, members of the public are much less likely than scientists to perceive GM foods as safe. The legal and regulatory status of GM foods varies by country, with some nations banning or restricting them, and others permitting them with widely differing degrees of regulation.

5 Inception and Generation Advancement of *Bt* Brinjal Genotypes at BARI

In 2005, two scientists of BARI Dr Al Amin of Biotechnology Division and Dr Shahabuddin Ahamed of HRC, BARI, visited Mahyco Agricultural Research Station, Jalna, Maharashtra, India, with nine Bangladeshi popular brinjal cultivars. These two scientists hybridized nine varieties with candidate brinjal plants containing *Bt* gene of Mahyco and collected F_1 seeds. A backcross (BC_1) was done there and the resultant seeds were brought back to Bangladesh. BARI initiated research activities under the ABSP II programme as follows:

2005 : Hybridization of nine Bangladeshi brinjal cultivars with *Bt* brinjal variety at Mahyco and F_1 seeds were collected and backcrossing programme initiated (BC_1) at Mahyco, India.

2006 : BC_2 done at BARI, Bangladesh.

2007 : BC_3 done at BARI, Bangladesh.

2008 : BC_3 (F_2) done at BARI, Bangladesh.

2009 : BC_3 (F_3) and BC_4 done at BARI, Bangladesh.

2010 : BC_3 (F_4), BC_5 done at BARI, Bangladesh.

Next season multi-location confined field trials (MLCTs) conducted at seven locations.

2011 : BC_3 (F_5) done at BARI, Bangladesh. Nine varieties underwent MLCTs in seven locations.

2012 : MLCTs repeated in seven locations.

2013 : MLCTs were repeated in the same seven locations.

5.1 Performance of *Bt* Brinjal Lines under Confined Trials

At Gazipur, all the *Bt* brinjal lines gave higher fruit yield (135.2% to 254%) than the corresponding non-*Bt* controls (Table 5). At all other locations only two to three *Bt* varieties were used with their corresponding non-*Bt* varieties. In every locations fruit yield of *Bt* varieties were higher than the corresponding non-*Bt* varieties. Multi-location confined field trials using nine *Bt* brinjal varieties, namely, Islampuri, Chaga, Dohazari, ISD 006, Kazla, Khatkhatia, Singnath, Nayantara and Uttara along with their non-*Bt* controls at Joydebpur, Jamalpur, Jessore, Hathazari, Rahamatpur, Ishurdi and Rangpur, during 2008-09, 2009-10, 2010-11 and 2011-12. In all the trials, plants and the fruits of *Bt* varieties were found similar in appearance

to their non-*Bt* counterparts. However, marketable fruit yields were significantly higher in all *Bt* brinjal varieties compared to those of the same non-*Bt* varieties. Yield damaged by fruit and shoot borer was also significantly lower (Fig. 11) in *Bt* brinjal varieties than their non-*Bt* counterparts (Biotechnology Division, BARI).

Table 5. Marketable fruit yield of *Bt* brinjal varieties and same non-*Bt* brinjal varieties under confined field trial conditions at Gazipur during 2010-11 and 2011-12

Variety	Marketable fruit yield/plant (kg)		Mean (kg)	% increase
	2011-12	2010-11		
<i>Bt</i> Nayantara	1.51	1.79	1.65	222
Non- <i>Bt</i> Nayantara	0.31	1.17	0.74	-
<i>Bt</i> Signath	0.85	2.89	1.87	183
Non- <i>Bt</i> Signath	0.19	1.84	1.02	-
<i>Bt</i> ISD 006	1.78	2.61	2.20	207
Non- <i>Bt</i> ISD 006	0.51	1.61	1.06	-
<i>Bt</i> Islampuri	-	1.46	1.46	153.6
Non- <i>Bt</i> Islampuri	-	0.95	0.95	-
<i>Bt</i> Kazla	2.59	3.45	3.02	185.3
Non- <i>Bt</i> Kazla	1.23	2.02	1.63	-
<i>Bt</i> Uttara	2.57	2.00	2.29	199.1
Non- <i>Bt</i> Uttara	1.04	1.25	1.15	-
<i>Bt</i> Dohazari	1.10	2.20	1.65	135.2
Non- <i>Bt</i> Dohazari	0.34	2.09	1.22	-
<i>Bt</i> Khat Khatia	1.47	3.38	2.43	152.8
Non- <i>Bt</i> Khat Khatia	0.44	2.73	1.59	-
<i>Bt</i> Chaga	1.90	3.08	2.49	254.1
Non- <i>Bt</i> Chaga	0.91	1.06	0.99	-

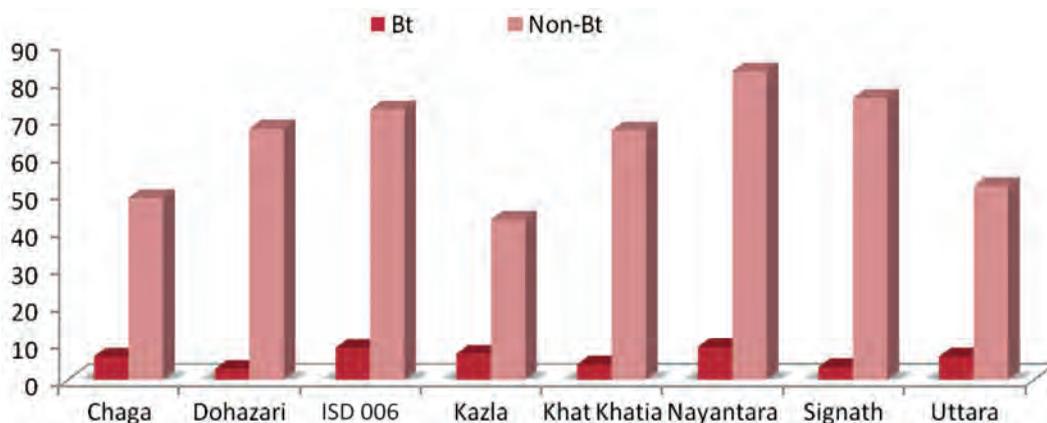


Fig. 11. Infested fruits (%) by BSFB in eight *Bt* brinjal varieties and their non-*Bt* varieties at Joydebpur

5.2 Brief Description of Released *Bt* Brinjal Varieties

A brief description of the released *Bt* brinjal varieties are given below (Mondal and Rahman, 2016; Mondal *et al*, 2014):

1. **BARI *Bt* Begun-1 (Uttara)** : Plants are spreading type, plant height 70-80 cm, fruits are cylindrical, colour rosey, fruit weight 60-70 g/fruit, fruit yield 48-57 mt/ha (Fig. 12).



Fig. 12. BARI *Bt* Begun-1 (Uttara)

2. **BARI *Bt* Begun-2 (Kazla)** : Plants are spreading type, plant height 65-75 cm, fruits are semi- circled to cylindrical, fruit colour blackish blue, fruit weight 60-70 g/fruit and fruit yield 45-54 MT/ha (Fig. 13).



Fig. 13. BARI *Bt* Begun-2 (Kazla)

3. **BARI *Bt* Begun-3 (Nayantara)** : Plant are medium erect, plant height 110-120 cm, fruits are round, fruits colour blackish blue, fruit weight 120-130 g, fruit yield 40-45 MT/ha (Fig. 14).



Fig. 14. BARI *Bt* Begun-3 (Nayantara)

- 4. BARI *Bt* Begun-4 (ISD 006) :** Plants are medium erect, plant height 100-110 cm, fruit type round (egg shaped), fruit weight 200-230 g/fruit, fruit colour greenish, fruit yield 35-42 MT/ha (Fig. 15).



Fig. 15. BARI *Bt* Begun-4 (ISD 006)

Advantages of Cultivation of *Bt* Brinjal Varieties

- *Bt* brinjal plants and fruits are protected from the infestation of the shoot and fruit borer.
- Farmers can keep their own seeds for the next season because the varieties are not hybrid.
- Farmers will not be dependant to any seed company for brinjal seeds for next season sowing.
- Use of insecticides are reduced and there will not be worries about health hazards.
- The final cost of production of brinjal is reduced and farmers are financially benefitted.

6 Commercialization of *Bt* Brinjal

6.1 Seed Production Program of *Bt* brinjal Varieties at BARI

After approval of the varieties, the Biotechnology Division of BARI started multiplication of seeds in the *rabi* season of 2013-14. Later, a 3-year seed production program was initiated by BARI in 2014 which was financed by the MoA to produce enough seeds of the four released varieties of *Bt* brinjal. The program was implemented by Seed Technology Division of BARI in collaboration with Biotechnology Division and HRC. Adequate seeds of four varieties were produced under this program (Table 6). Recently, Bangladesh Agricultural Development Corporation (BADDC), a government owned input supply organization, is also producing *Bt* brinjal seeds. At the same time, a number of private seed companies also applied to BARI for seed production and marketing of *Bt* brinjal but the decision yet to be finalized.

Table 6. Seed production of *Bt* brinjal varieties by Seed Technology Division, BARI during 2014-15, 2015-16 and 2016-17

Year	BARI <i>Bt</i> Begun-1	BARI <i>Bt</i> Begun-2	BARI <i>Bt</i> Begun-3	BARI <i>Bt</i> Begun-4	Total (kg)
2014-15	0.80	28.5	4.50	4.50	38.3
2015-16	153.5	184.0	84.0	239.0	660.5
2016-17	234.0	337.0	202.0	245.0	1,018.0
Total	388.3	549.5	290.0	488.5	1,716.3

(Source: Seed Technology Division, BARI)

6.2. Distribution of Seedlings among the Farmers

The first *Bt* brinjal seedling distribution program was held on January 22, 2014 at BARC where Chief Guest was Hon'ble Agriculture Minister, Matia Chowdhury, MP. *Bt* brinjal seedlings were distributed among 20 farmers of Gazipur, Pabna, Rangpur and Jamalpur districts (Fig. 16). The farmers successfully cultivated the distributed seedlings and sold the produce in the market. As a result, the farmers were economically benefited. However, couple of farmers did not follow the cultivation instructions properly and thus they did not get the desired results.



Fig. 16. Hon'ble Agriculture Minister, Matia Chowdhury, MP distributing *Bt* brinjal seedlings at BARC

6.3 Progress of *Bt* brinjal Cultivation on the Farmers' Fields

During the winter season of 2014-15, On Farm Research Division (OFRD) of BARI started to study the performance of four *Bt* brinjal varieties in the farmers' fields. During winter season of 2014-15, a total of 108 farmers of 19 districts; in 2015-16 total of 250 farmers of 25 districts; in 2016-17 total of 512 farmers in 29 districts; in 2017-18 total of 5500 farmers of 36 districts (Table 7) cultivated *Bt* brinjal. Yield performance of *Bt* brinjal in the farmers' fields was very satisfactory compared to non-*Bt* counterparts (Table 8). Farmers are very happy with the *Bt* brinjal Varieties. They observed that the fruits of *Bt* brinjal varieties were free from insect infestation, production cost is less and neighbouring farmers were interested for seeds of *Bt* brinjal for growing in next season. From 2014 to 2016, only OFRD of BARI worked in the farmers' fields with the four *Bt* brinjal varieties all over the country. OFRD arranged training programs for farmers on production technology, field days on

Table 7. *Bt* brinjal in the farmers' fields from 2014 to 2017-18

Planting season	Cultivation period	Number of farmers cultivating <i>Bt</i> brinjal	Acreage (ha)
Spring 2014	Jan. - Jun.	20	2.50
Winter 2014-15	Nov. to Mar. - Apr.	108	15.00
Winter 2015-16	Nov. to Mar. - Apr.	250	33.00
Winter 2016-17	Nov. to Mar. - Apr.	512	68.30
Winter 2017-18	Nov. to Mar. - Apr.	5500	366.70

Source: OFRD, BARI



Fig. 17. BARI Bt Begun-1 on the farmers' fields at Ishurdi, Pabna



Fig. 18. BARI Bt Begun-4 on the farmer's field at Ishurdi, Pabna

Table 8. Performance of four *Bt* brinjal varieties at different locations during 2014-15, 2015-16 and 2016-17

Variety	No. of locations			BSFB infestation						Yield (t/ha)		
				Shoot (%)			Fruit (No.)					
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
BARI <i>Bt</i> Begun-1	8	3	–	0.03	0.38	–	0.84	0.86	–	22.16	22.4	–
Non- <i>Bt</i> (Uttara)	8	3	–	33.03	35.3	–	49.82	57.9	–	13.21	12.2	–
BARI <i>Bt</i> Begun-2	13	14	28	0	0.11	0.27	0	0.21	0.34	28.25	29.1	35.88
Non- <i>Bt</i> (Kazla)	13	14	28	36.45	31.26	25.85	49.22	50.43	49.83	12.40	16.51	16.56
BARI <i>Bt</i> Begun-3	16	14	15	0.07	0.09	0.15	1.14	0.31	0.16	21.96	25.29	21.57
Non- <i>Bt</i> (Nayantara)	16	14	15	12.84	37.27	23.14	50.99	56.13	48.79	12.21	11.1	13.80
BARI <i>Bt</i> Begun-4	7	17	2	0	02.8	0.28	0.04	03.2	0.28	23.89	22.5	22.08
Non- <i>Bt</i> (ISD 006)	7	17	21	42.58	27.53	25.81	53.28	47.52	40.56	10.57	11.1	14.35

Source: OFRD, BARI

the farmers' fields and also farmers' rallies on *Bt* brinjal. Local public representatives, farmers and other interested farmers participated in the training programs and field days. Number of *Bt* brinjal cultivating farmers is significantly increasing year after year. From the winter season of 2016-17, Department of Agricultural Extension (DAE) started to distribute *Bt* brinjal seeds to the farmers. During 2017-18, DAE distributed *Bt* brinjal seeds to about 7500 farmers.

Every year number of farmers is increasing because some interested farmers are collecting seeds for growing in next season from those farmers who have been growing *Bt* brinjal varieties. Those farmers who have obtained *Bt* brinjal seeds from farmers have not been included in Table 7, meaning thereby, that the total number of farmers growing *Bt* brinjal during 2017-18 would be more than 7500.

6.4. Socio-Economic Performance of *Bt* Brinjal

A socio-economic study was conducted by Rashid *et al* (2018) in 35 districts of Bangladesh during 2016-17 and reported that *Bt* brinjal cultivating farmers received 13% higher yield compared to those cultivated non-*Bt* brinjal varieties. Farmers belonging to former category also received significantly higher gross return (21%) and net income (83%) compared to the farmers belonged to latter

category because of higher selling price and yield. The benefit cost ratio over total cost was also more than 13% higher for *Bt* brinjal cultivating farmers. The total variable cost and fixed cost were also lower for *Bt* brinjal cultivating farmers compared to non-*Bt* brinjal cultivating farmers, respectively (Table 9).

Table 9. Profitability differential in cultivation of *Bt* brinjal vs non-*Bt* brinjal varieties by the farmers

Particulars	<i>Bt</i> farmers		Non- <i>Bt</i> farmers		Mean difference	P (T<=t)
	Amount	SD	Amount	SD		
A. Returns						
Yield (t/ha)	23.21	6.33	20.19	4.23	3.02***	0.000
Gross return (*Tk./ha)	394570	1727	312945	1387	81625***	0.000
Gross margin (Tk./ha)	248651	1756	101590	1532	14706***	0.000
Net return (Tk./ha)	179602	2291	29841	3894	149761***	0.000
B. Cultivation cost (Tk.)						
Fixed cost (FC)	69049	2558	71749	1840	-2700	0.142
Variable cost (VC)	145919	827	211355	1970	-65436***	0.000
Total cost (TC)	214968	1136	283104	4048	-68136***	0.000
C. Benefit cost ratio (BCR)						
Over VC	2.70	0.017	1.48	0.011	1.22***	0.000
Over TC	1.84	0.014	1.11	0.015	0.73***	0.000

Source: Rashid *et al* (2018)

*1 USD = Tk. 83.00

Writing in the peer-reviewed journal *Frontiers in Bioengineering and Biotechnology*, the scientific team, led by Cornell University's Professor Tony Shelton, revealed that during the year 2018, 27,012 Bangladeshi farmers benefited from the pest-reducing technology. A study in the 2016-17 cropping season compared 505 *Bt* brinjal growing farmers with 350 non-*Bt* brinjal growing farmers. This indicated a 61% saving in pesticide cost, which translated to a 650% (six-fold) increase in returns, from \$2,151/ha for *Bt* brinjal as compared to just \$357/ha for non-*Bt* brinjal. These cost savings and increases in returns show not just a significant environmental gain due to pesticide reductions, but a huge potential improvement in livelihoods for these farmers, many of whom live in impoverished conditions (Shelton *et al*, 2018).

7 Farmers' Interview

Many farmers who have been cultivating *Bt* brinjal expressed their satisfaction as their income increased significantly. Excerpts of interaction with few farmers are shared below:

i. **Name of farmer and district :** **Mr. Milon Mia**, Bogra District

Question : What is your name and how old are you?

Answer : My name is Milon Mia. I am 36 years old.

Question : Are you growing *Bt* brinjal? What are the differences between *Bt* brinjal and traditional brinjal?

Answer : Yes, I am growing *Bt* brinjal in my field. One of the main differences between *Bt* brinjal and other brinjal is that there is no infestation of shoot and fruit borer in *Bt* brinjal. But in our traditional brinjal varieties, shoot and fruit borer insect are present and I used to spray insecticide every 2-3 days in the past. The yield of *Bt* brinjal variety is also higher than the traditional brinjal variety. I would lose about 40% of my crop due to pest damage and the size of fruits will be smaller than that of the *Bt* brinjal. With *Bt* brinjal, I don't need to use pesticide to control the insect because there is no infestation of the insect. All my neighbours are excited and they say, what is this?

Question : Did any other farmer asking for seeds from you of *Bt* brinjal?

Answer : Yes, all my neighbours are excited and they are asking for *Bt* brinjal seeds from me. I also suggested them to collect seeds from BARI and BADC.

Question : Did you eat *Bt* brinjal?

Answer : Yes, my wife cooked *Bt* brinjal and we ate. I and my wife are very much happy with this brinjal, so next year I will grow it again.



ii. Name of farmer and district : Mr. Hafizur Rahman, Tangail District

Question : What is your name? Where are you from?

Answer : My name is Hafizur Rahman. I am from Tangail District.

Question : Are you growing *Bt* brinjal ? Would you please say few words about growing *Bt* brinjal in your field?

Answer : Yes, I have been growing *Bt* brinjal for last two years. Earlier, I was a traditional brinjal farmer, I used to grow traditional brinjal in the past and I used to spray insecticides every 2-3 days to control the insect. But now I am growing *Bt* brinjal so I don't need to spray because there is no shoot and fruit borer infestation. I am very happy; the yield is also higher and it is economically very profitable. I will grow *Bt* brinjal next year again.



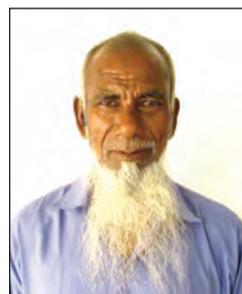
iii. Name of farmer and district : Md. Afjal Hossain, Pirghanj, Rangpur

Question : What is your name ? How old are you?

Answer : My name is Md. Afjal Hossain. I am 65 years old.

Question : Did you grow *Bt* brinjal in your field?

Answer : Yes, I have been growing *Bt* brinjal since 2014. I took seedlings of *Bt* brinjal from the hands of Agriculture Minister, Begum Matia Choudhury in 2014 at Dhaka. During 2014-2017, I grew *Bt* brinjal. A lot of visitors came to see my brinjal field. Many journalists, foreigners and a large number of farmers visited my field. I am very much happy with the *Bt* brinjal. It is very much profitable. No need to spray insecticides. Production cost is also very low compared to traditional brinjal. I like *Bt* brinjal very much. I supplied *Bt* brinjal seeds to at least 150 farmers. Now they are also growing *Bt* brinjal on their farms.



8

Consumers' Perception

In 2014 and 2015 there were a lot of confusions regarding consumption of *Bt* brinjal among the consumers. Now the consumers' perception has changed, because they understand that there is no use of pesticide in *Bt* brinjal, so it is very safe. Now the consumers opting for *Bt* brinjal without any doubts for their consumption. We have interacted with more than 10 persons to know about the consumers' reactions on *Bt* brinjal and perception of the following three is mentioned below:

i. Name of Consumer : Md. Anisur Rahman

Village : Raniganj, Upazilla: Ghoraghat, Zilla: Dinajpur

Question : What is your Name and how old are you?

Answer : My name is Md. Anisur Rahman and I am 65 years old.

Question : What is your occupation?

Answer : I am a business man but I also look after crop production of my own land.

Question : Have you heard about *Bt* brinjal?

Answer : Yes, I have heard about *Bt* brinjal.

Question : Would you please say what you know about *Bt* brinjal?

Answer : I attended in a field day of *Bt* brinjal crop in the village of Kasiatola which is my neighbouring village. In that village there were two *Bt* brinjal grown fields. At the fruiting stage a field day was arranged by agriculture department and they invited us. In that field day, a number of agricultural scientists and extension officers spoke. They said that in the *Bt* brinjal crop there will be no infestation of shoot and fruit borer and there is no need of insecticide spray although we know that for brinjal cultivation, use of insecticide is must and sometimes, it needs to spray more than 100 times in a growing season. But now I know in case of *Bt* brinjal very little use of insecticide is required so it is very safe for consumption. After that field day, I collected brinjal fruits from that farmer and consumed. In the following year, I collected seeds of *Bt* brinjal and cultivating every year on my farm. Now I know very much about the *Bt* brinjal.



ii. Name of Consumer : Md. Mahe Alam Siddique Mitu

Village : Bashpokuria, Upazilla: Pirganj, Zilla: Rangpur

Question : What is your name and how old are you?

Answer : My name is Md. Mahe Alam Mitu and I am 35 years old.

Question : What is your occupation?

Answer : I am a business man. I also have a poultry farm and I have some agricultural land.

Question : Have you heard about *Bt* brinjal?

Answer : Yes, I have heard about *Bt* brinjal.

Question : Would you please say what you know about *Bt* brinjal?

Answer : At first, I knew about *Bt* brinjal from the farmer Md. Afjal Hossain of my village. He has been cultivating *Bt* brinjal since 2014. I visited several times his fields. During fruiting time, I bought some brinjal from him. Our whole family regularly consumes *Bt* brinjal and Mr. Afjal regularly supplies *Bt* brinjal to us. I attended in a training programme on *Bt* brinjal at the beginning of the season on cultivation technique and a field day of *Bt* brinjal crop at fruiting stage in our village which was arranged by BARI and DAE. They invited me.

In those field days and training programmes, a number of agricultural scientists and extension officers came. They said that there will be no infestation of shoot and fruit borer insect and there is no need of insecticides spray in the *Bt* brinjal crop. Although, we know that in brinjal cultivation, use of insecticide is urgently needed and sometimes, it needs to spray more than 100 times in a growing period. But now I know that in case of *Bt* brinjal very little use of insecticide is needed so it is very safe for consumption. I also collected booklets on *Bt* brinjal. I know very much about the *Bt* brinjal and its merits.



iii. Name of Consumer : Mrs. Karimunnahar

Address : BARI Campus. Joydebpur, Gazipur

Question : What is your name and how old are you?

Answer : My name is Karimunnahar and I am 30 years old.



Question : What is your occupation?

Answer : I am a school teacher and at the same time I am a housewife.

Question : Where do you live? And where are you from?

Answer : I live in the BARI Campus and I am from Mymensingh district

Question : Have you heard about *Bt* brinjal?

Answer : Yes, I have heard about *Bt* brinjal.

Question : Would you please say what you know about *Bt* brinjal?

Answer : Initially I learnt about *Bt* brinjal from the Biotechnology Division of BARI. Dr Dil Afroz, CSO, told me about *Bt* brinjal. They have been growing *Bt* brinjal in their greenhouse and research fields. I visited several times their green house and field. During fruiting time, I collected some brinjal fruits from them. Our whole family regularly consumes *Bt* brinjal and my husband regularly collects *Bt* brinjal for family consumption. I attended a training programme on *Bt* brinjal and a field day of *Bt* brinjal crop at fruiting stage which were arranged by Biotechnology Division of BARI. They invited me to the field days and demonstration programmes.

They said that there will be no infestation of shoot and fruit borer insect and there is no need to use of insecticide spray in the *Bt* brinjal crop, although, we know use of insecticide is very high for brinjal cultivation, but now I know, in case of *Bt* brinjal, that very little use of insecticide is required so it is very safe for consumption, I also collected booklets on *Bt* brinjal. Now I know very much about the *Bt* brinjal and its advantages. Director General of BARI, in one programme, informed us that the *Bt* brinjal fruits were tested in a famous Covance laboratory of London. They reported that there is no harmful element in *Bt* brinjal and it is very safe for consumption. Now consumers are happy with the *Bt* brinjal. In our home garden, we regularly grow *Bt* brinjal.

9 Conclusions

Cultivation of *Bt* brinjal on the farmers' fields with the four *Bt* brinjal varieties was started by only 20 farmers in Bangladesh since 2014. Currently during 2018, the number of farmers who are cultivating *Bt* brinjal varieties has increased to more than 7500. Initially there were some hesitations among the farmers to cultivate *Bt* brinjal, because there was propaganda against the *Bt* brinjal by some anti-GM technology activists including media/press.

Bangladeshi farmers and consumers are convinced that by cultivating *Bt* brinjal they will be benefited because (i) there was no infestation of shoot and fruit borer insect, (ii) they can keep their own seeds for next season because varieties are not hybrid, (iii) they will not be dependant to any particular seed company for buying *Bt* brinjal seeds every year, (iv) use of insecticides will be reduced and they will not be worried about health hazards, (v) cost of production will be reduced, and finally brinjal cultivation will be profitable and farmers will be economically benefitted. Also, it is safe to consume by the consumers.

On the basis of successful experience of cultivating the *Bt* brinjal varieties by thousands of farmers in Bangladesh, it can be concluded that the biotechnological tools can be successfully utilized in solving the biotic stresses like insect and disease infestation of other important crops and abiotic stresses like drought, salinity and high/low temperature for crop production which could not be solved easily through conventional breeding. It is also suggested that the international development partners should come forward to support this type of research initiatives in the developing countries of the world. International development partners and donor agencies should work jointly for funding to this type of research project. However, the enabling political environment and political support to promote the science-based technologies and innovations are equally important to play a significant role for its adoption, as has been demonstrated by the government of Bangladesh due to the visionary approach of the political leadership. *Bt* brinjal story, experienced in Bangladesh, can be emulated for ensuring food and nutritional security, improving the livelihoods of the smallholder farmers and protecting the environment in other developing countries also.

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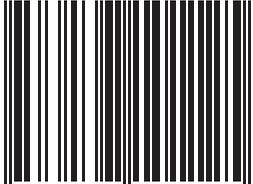
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ISBN 978-616-7101-12-5



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