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# Innovation in Agriculture and Industrial sectors of Bangladesh through application of Biotechnology to achieve SDGs: *Opportunities and Challenges*

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## Abstract

*Bangladesh is an agroeconomic country with a large population compared to its land area and resources. Country's population projected to reach 265.8 million by 2050 and food demand is expected to be much higher than that of production. Food production for its huge population would have to achieve in adverse climatic conditions. Therefore, there is a growing demand to develop stress tolerant crop varieties to combat climate change induced disasters like flood, drought and intrusion of salinity. Improvement of fisheries & livestock, biodiversity conservation, waste management, health care, forestry and environment sectors deserve much attention with innovative approaches. Biotechnology and human civilisation are rolling together side by side from the very beginning of history, but the story of modern biotechnology is about four decades. During this period, biotechnology has changed the world through considerable progress in agriculture, health, environment, industrial sectors and so on. Recently, biotechnology has developed breakthrough products and technologies to fight diseases, reduce environmental harm, feed the hungry, use less & cleaner energy and have safer, cleaner and more efficient industrial manufacturing processes. So far, more than 250 biotechnology health care products and vaccines have been made available to patients, many for previously untreatable diseases and millions of farmers around the world use agricultural biotechnology to increase yields, prevent damage from insects, pests and reduce harm on environment due to farming. Bangladesh has achieved considerable progress in agriculture biotechnology through traditional process. But other sectors, specially industrial, health and environment need much attention and agriculture sector march toward modern biotechnology to keep patch with demand of population growth. Significant initiatives have been taken by the Government of Bangladesh to promote biotechnological research and infrastructure development. We emphasis on next innovative approaches in biotechnology to have significant impact on economic development to achieve sustainable development goals (SDG).*

**Keywords:** Agriculture, Bangladesh, Biotechnology, Industry, Innovative approach, SDG.

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## 1. Introduction

The UN Committee for Development Policy (CPD) has declared Bangladesh's eligibility for progression from Least Developed Country to Developing Country. This has been achieved through fulfilment of requirements in March 2018 and could receive official Developing Country status by 2024. This success also brings confidence for achieving the SDGs. In the last 15 years, Bangladesh has perceived one of the fastest reductions in poverty with limited resources. The country has met the target in reducing the proportion of population below the national poverty line (currently 22.4%) three years ahead of time. As one of the top performing countries in terms of reaching the Millennium Development Goals, Bangladesh is equally confident in embracing the SDG targets and the Prime Minister has expressed her deep commitment to achieving these before the year 2030.

But, to achieve the SDGs, Bangladesh faces some substantial challenges. The Sustainable Development Solution Network has published a global report on the SDGs of 149 countries, ranking them in terms of their 2015 status on each of the goals. According to the report Bangladesh ranks last (118) among the BIMSTEC countries and second last among the SAARC countries. According to the estimates in the final report by the Intergovernmental Committee of Experts on Sustainable Development Financing (ICESDF), achieving the SDGs in all countries will require additional global investments up to 2030. A country like Bangladesh will need a huge investment for basic infrastructure and agriculture sectors, climate change mitigation, health and education.

Bangladesh has achieved self-sufficiency in food grain production due to the blessings of agricultural Biotechnology. Gross Domestic Products (GDP) from Agriculture in Bangladesh averaged 9012.60 BDT Million from 2006 until 2019. However, to keep patch with demand of growing population such food, health, medicine and to ameliorate with climate change emphasis should be given all sectors of biotechnology to achieve SDGs (SDGS 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. In other word "Production of goods and services using biological organisms, systems and process". Biotechnology and human civilisation are rolling together side by side undoubtedly from the very beginning of history, but the story of modern biotechnology is not more than four decades old. We are in a place of being blessed with the fruits of biotechnology from dawn to dusk (Md. Salimullah, 2016).

Discovery of the structure of Deoxyribonucleic acid (DNA) by Watson and Crick in 1953 was the most significant finding in 20th century. This discovery in 1970 has introduced a new era called genetic engineering in since 1970. Modern biotechnology is overpowering fictions one after another through amazing discoveries such as Insulin-producing bacteria for the treatment of Diabetes (Johnson, 1983; Ladisch & Kohlmann, 1992), making 'Dolly', the first clone of a sheep (Evans et al., 1999) or creating artificial life 'Synthia' introducing artificially synthesised genetic material into an organism (Sample, 2010). Stem cells from which scientists are now producing heart cell-like beating cells (Passier, van Laake, & Mummery, 2008; Wong & Bernstein, 2010) and differentiating them into other cell types (Passier et al., 2008).

For the last four decades biotechnology has been changing the world through considerable progress in agriculture (Borlaug, 2000), health (Read & Lee Jr, 1994), environment (Sayler, Fox, & Blackburn, 2013; Scragg, 2005), industry (Hatti-Kaul, Törnvall, Gustafsson, & Börjesson, 2007) and so on. Recombinant DNA technology has proved beyond doubt its applicability in broad areas of human welfare. Specially developing world with changing climate and increased population are now concentrating on the exploitation of the golden pit of biotechnology. Many Asian countries (Chaturvedi & Rao, 2004), namely India, China, Philippines, Thailand, Pakistan, Malaysia, and Vietnam have recognised the potential of these techniques in economic growth (Swaminathan, 1982). They have made significant steps in the development and commercialisation of biotechnology over more than two decades. Our neighbouring country, India has taken the advantages of this technology in a wide variety of areas, including crop management, forestry, biopesticides, and biofertilizers (Chaturvedi, 2005). Kenya has taken national policy in developing transgenic plants resistant to pathogens or environmental stress as well as vaccines for livestock (Qaim, 1999). Bangladesh has showed that it is also in the race with the whole genome sequence of Jute and introducing genetically modified (GM) Bt-brinjal.

Biotechnology contributes to solving problems like food, health and other fundamentals needs that hinder development in the developing world. The lack of facilities and professional skills in biotechnology limits R & D initiatives in the developing and the least developed countries (LDCs). The practice of biotechnology in many developing countries is nevertheless impressive. The establishment of biotechnology infrastructure in Bangladesh is indicative of biotechnology being accorded as significant in the eradication of poverty for human and social welfare (DaSilva, Baydoun, & Badran, 2002).

## 2. History of Biotechnology and Genetic Engineering

People have been manipulating living things to solve problems and improve his way of life for millennia. The term biotechnology was coined in 1919 by Karl Ereky. At that time, the term meant by which products are produced from raw materials with the aid of living organisms. Although now most often associated with the development of drugs, historically biotechnology has been principally associated with food such as malnutrition and famine.

Early agriculture focused on producing food. Plants and animals were selectively bred, and microorganisms were used to make food items such as beverages, cheese and bread. The history of biotechnology begins on brewing techniques for beer. The ancient Egyptians made wine using fermentation techniques based on microbiological processes and to make dough rise during bread making.
The late eighteenth century and the beginning of the nineteenth century saw the advent of vaccinations, crop rotation and animal drawn machinery. The end of the nineteenth century was a milestone of biology. Microorganisms were discovered, genetics was discovered by Mendel and fermentation & other microbial processes were established by Koch, Pasteur and Lister.

Biotechnology at the beginning of the twentieth century began to bring industry and agriculture together. In 1928, Alexander Fleming discovered the mold Penicillium. In 1940, penicillin became available for medicinal use to treat bacterial infections. The biotechnical focus moved to pharmaceuticals. The field of modern biotechnology is thought of as having been born by discovery of DNA in 1953 and gene splicing in 1971 by Paul Berg's.

Significantly advance was made in 1972 by transferring genetic material into a bacterium, which enabled the imported material to reproduce. In 1978, Boyer isolated a gene for insulin from Human DNA using biotechnology. In the 1980s, testing of biotechnology-derived foods began and after its FDA approval in 1994, the FlavrSavr® tomato gave consumers a more flavourful tomato that stays fresh longer. History of Biotech can be divided into three phases (Manikondu, 2017).

### 2.1 Ancient Biotechnology (Pre-1800)

Most of the biotech developments before the year 1800 can be termed as discoveries or developments. These inventions were based on common observations about nature.

### 2.2 Classical Biotechnology (1800-1945)

The Hungarian Károly Ereky coined the word "biotechnology" in 1919 to describe a technology based on converting raw materials into a more useful product. In a book entitled Biotechnologie, Ereky further developed a theme that would be reiterated through the 20th century: biotechnology could provide solutions to societal crises, such as food and energy shortages. The ability of microorganisms to produce acids and gasses as a result of normal cell metabolism has been taken advantage of to make new and exciting foods for generations. Examples include production of beer, cheese and bread.

### 2.3 Modern Biotechnology (1945-present)

The origins of biotechnology culminate with the birth of genetic engineering. There were two key events that have scientific breakthroughs to unite genetics with biotechnology. One was the discovery of DNA structure (1953) and the other was discovery a recombinant DNA technique (1973) by which a section of DNA was cut from the plasmid of an E. coli bacterium and transferred into the DNA of another; popularly referred to as "genetic engineering,".

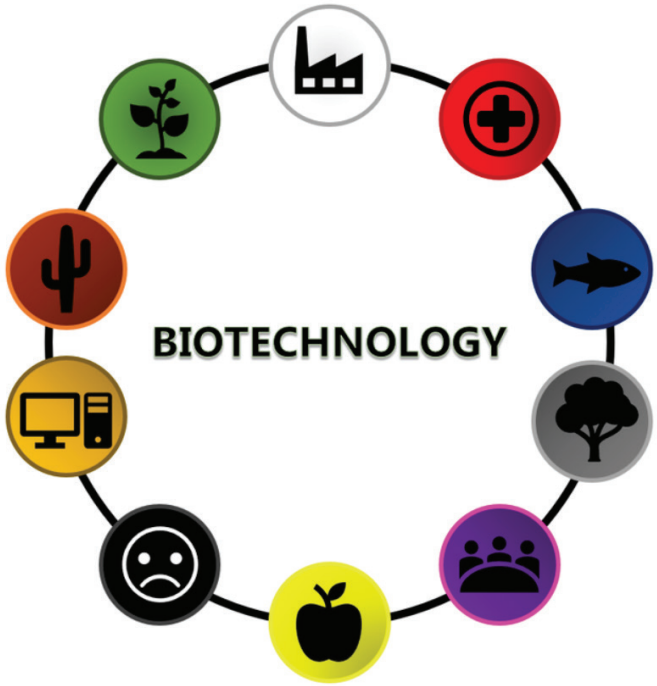
Recent development in molecular biology have given Biotechnology a new meaning, horizon and potential through the application of recombinant DNA technology. New biotechnology to modify the genetic material of living cells to produce new substances or perform new functions. Gene technology or genetic engineering allows the biologist to take a gene from one cell and insert it into another cell which may be plant, animal or microbes or to produce new combinations of genes.

## 3. Scope & Importance of Biotechnology:

Biotechnology has rapidly emerged as an area of activity having a noticeable realized as well as potential impact on virtually all domains of human welfare, ranging from food producing & processing, protecting the environment to human health. Genetic engineering in biotechnology stimulated hopes for both therapeutic proteins, drugs and biological organisms themselves, such as seeds, pesticides, engineered yeasts and modified human cells for treating genetic diseases. The field of genetic engineering remains a heated topic of discussion today with the advent of gene therapy, stem cell research, cloning, and genetically-modified food (Kumar). As a result, it now plays a very important role in employment, production and productivity, trade, economics and economy and the quality of human life throughout the world. This is clearly reflected in the creating of numerous biotechnology companies throughout the world, and the movement of noted scientists. The total volume of trade in biotechnology products in increasing sharply every year, and it would soon become the major contributor to the world trade. Many commentators are confident that the 2lst century will be the century of biotechnology, just as the 20th century was the era of electronics.

## 4. Branches of Biotechnology:

There are basically ten divisions in biotechnology, but sometimes hard to define its borders. The most prominent ones include white, red and green biotechnology, but the others are very interesting & important as well. Now we will try to clarify them one by one.




| | |
|---|---|
| Green | Processes improving Agriculture |
| White | Industrial process involving Microorganisms |
| Red | Medicine and Human Health |
| Blue | Marine Biotechnology |
| Yellow | Food and Nutrition |
| Grey | Environmental Biotechnology |
| Gold | Bioinformatics, Computer Science |
| Brown | Biotechnology for deserts and dry seasons |
| Violet | Laws, ethics, philosophy |
| Dark | Bioterrorism, biological warfare |

### 4.1 Green Biotechnology

Green biotechnology focuses on technologies that have positive impact on agriculture. This includes creation of new crops using genetic or traditional approaches as well as creation of new biofertilizers or biopesticides. This branch gives hope that one day food will be a commodity everyone can wish. The term "golden rice", containing genes of daffodil to produce β-carotene-precursor of vitamin A is a good example. Over 230 million people in Asian suffer from night blindness due to deficiency of vitamin A. Golden rice could help fight this problem.

### 4.2 White Biotechnology

White biotechnology, also known as industrial biotechnology, involves employment of microorganisms in production process. An example is the budding yeast in production of wine, bread or beer. White biotechnology also encompasses production of biodegradable polymers, important compounds, antibiotics, industrial enzymes & microorganisms and fuel from renewable sources. In addition, it also aims in designing processes and products that consume little resources and energy compared to traditional methods. It is considered as the biggest branch of biotechnology.

### 4.3 Red Biotechnology

Red biotechnology specializes in medicine and human health. This includes production of new antibiotics, vaccines, antibodies, medicaments, as well as genetic engineering for disease treatment. This part of biotechnology is extremely important for our wellbeing and quite profitable. For example; monoclonal antibodies, DNA probes, synthetic vaccines, valuable drugs like insulin, interferon, and growth hormone etc; Gene therapy to cure genetic diseases, babies of specified sex and identification of parents/criminals using DNA fingerprinting from even blood or semen stains, hair roots etc.

### 4.4 Blue Biotechnology

Blue biotechnology focuses on marine organisms. Basically, it involves use of marine organisms or their products for creation of new medicaments, cosmetics, food or food supplements. The sea represents the greatest biodiversity, there are potentially a huge range of sectors to be benefited from the use of this kind of biotechnology.

### 4.5 Yellow Biotechnology

Yellow biotechnology encompasses creation of new ways to improve certain food products or to obtain more nutrition-rich products. It also tries to eliminate allergens and other components from food that have intolerances. It is also closely related to green biotechnology.

### 4.6 Grey Biotechnology

Grey biotechnology tries to use living organisms to improve the environment. This includes bioremediation that uses microorganism or plants to clean up the environment from certain pollutants. It also tries to maintain biodiversity. The use microorganisms to break down pollutants in soil, air or groundwater including degradation of petroleum & oil spills, detoxification of industrial effluents; biocontrol of plant diseases and insect pests by using viruses, bacteria, amoebae, fungi etc. to avoids the use of pesticides which cause pollution.

### 4.7 Gold Biotechnology

Bioinformatics is the application and development of computational tools such as software in order to understand the large complex sets of data generated by the different biological functions. This field incorporates the knowledge of various fields such as statistics, mathematics, computer sciences, engineering and biology in order to analyse and present the data interpretation in an in silico (modelling/simulation) manner for further applications. It plays a vital role in areas like functional genomics, structural genomics and proteomics. It becomes a key contributor to Biotechnology and pharma sectors.

### 4.8 Brown Biotechnology

Brown biotechnology centres around treatment of desert-like soils drawing from species that are highly resistant to dry and saline soils. In this case the use of GMO technology could make a beneficial impact using improved seeds to grow high-value commercial crops in low-rainfall areas. Basically, development of varieties resistant to dry with enough crop yield. This branch is closely related to grey and green biotechnology.

### 4.9 Violet Biotechnology

It centres upon the study of the legal aspects that surround this science. Biotechnology is something quite controversial and potentially very dangerous. Thus, the need for regulation and formation of a platform for discussion was necessary. This also includes biosecurity and moral impact of certain technologies (gene therapy, animal testing, etc.).

### 4.10 Dark Biotechnology

Every herd has its black sheep. Dark biotechnology is not really something that anyone from science community takes part in, well, at least not in the bad part. It includes production of biological warfare and bioterrorism. It investigates pathogenic, virulent and resistant microorganisms to convert them into biological weapons or counteract their harmful effects.

## 5. Emergence Biotechnology and Genetic Engineering in Bangladesh

The research on biotechnology in Bangladesh started in 1970. The root cause behind was the significance of agricultural sector, which had been the backbone of the national economy since the ancient times. The research first started through tissue culture in Dhaka University (Md. Salimullah, 2016) and Bangladesh Agriculture University ("Biotechnology and genetic engineering in Bangladesh," 2019). Subsequently, similar research programs began to take place in other public universities, Bangladesh Rice Research Institute (BRRI), Bangladesh Jute Research Institute (BJRI), Bangladesh Agricultural Research Institute (BARI), Bangladesh Forest Research Institute, Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh Livestock Research Institute (BLRI) and Bangladesh Atomic Energy Commission (BAEC).

In the late 1990s, Bangladesh became a member of the International Centre for Genetic Engineering and Biotechnology (ICGEB). In 1997 a task force was formed to formulate biosafety guidelines and biosafety regulations. In 1999, the National Institute of Biotechnology (NIB) was started as a project to established the centre of excellence in biotechnological research (Chaturvedi & Rao, 2004) and has achieved its legal basis through enactment of National Institute of Biotechnology Act in 2010. To accelerate multidimensional biotechnological research, the government adopted the national policy guidelines on biotechnology which was approved by the National Task force on biotechnology ("Govt. approves national biotechnology policy guidelines," 2006). In 2012, the cabinet approved the National Biotechnology Policy with the aim to eradicate poverty through increasing productivity in agriculture and industrial sectors ("Cabinet okays draft of National Biotechnology Policy, 2012," 2012). On the light of Biotechnology policy government approved the National Biotechnology Policy action Plan in 2014 (Md. Salimullah, 2016). The NIB and the Ministry of Science & Technology jointly organised the first National Biotechnology Fair in Dhaka, Bangladesh in September 2018. This fair created awareness among mass besides highlighting the impact of Biotechnology.

## 6. Present Status of Biotechnology in Bangladesh

Initiatives have been taken by the Government to promote biotechnological research and infrastructure development to enhance productivity, quality and value of products, and environmental conservation leading to sustained food security, poverty alleviation and livelihood security. With an aim to accelerate the research activities in this field government has established NIB as a specialised institute. Different governing bodies, policies and guidelines are in shape to address, manage and co-ordinate biotechnological research and issues under relevant ministries.

## 6.1 Agriculture Biotechnology

### *6.1.1 Plant Biotechnology*

In Bangladesh, biotechnology program on plant tissue culture was initiated in the late 1970s. Within a span of several years, tissue culture research laboratories have been developed in different universities, R&D organisations and private entrepreneurs. Some NGOs have already marketed tissue cultured plantlets such as potato, banana and ornamental plants. Plant regeneration and micro-propagation protocols have been developed for different crops, forest, fruit, ornamental, medicinal and important plants as well as vegetables.

Besides developing better varieties, different organisations are also working on varieties capable of fighting natural calamities. Thus, research on transgenic plant development is going on in many laboratories' countrywide. BRRI have developed high-yielding modern varieties (MVs) of rice both for favourable and unfavourable ecosystem. So far they released 97 MVs (91 inbred and 6 hybrids) of rice. (Varietal Development, 2019).

Commendable progress has been made at the University of Dhaka in producing salt tolerant rice and cold tolerant jute varieties using molecular markers. Plant tissue culture development and commercialisation has been taken at the University of Rajshahi, they commercialized strawberries and some exotic flowers successfully. NIB has achieved micropropagation of different fruits and ornamental plants and has been working on transformation of stress tolerant genes into eggplant. BARI is the largest multi-crop research institute conducting research on a wide variety of crops, such as cereals, tubers, pulses, oilseeds, vegetables, fruits, spices, flowers, etc.

A team at the University of Dhaka led by Professor Zeba Islam Seraj made four transgenic rice varieties capable of production in high soil salinity, far better than the ones derived from conventional breeding. A pea gene 'helicase' was infused into four high yielding rice varieties (HYVs) that helped rice plants have higher salt tolerance and higher yield potential. Currently these varieties are in confined trials in greenhouse and on controlled field trials (Noor et al., 2019; Salam et al., 2010; Seraj, Elias, Biswas, & Tuteja, 2018; SERAJ, LISA, ISLAM, BEGUM, & DAS, 2006).

Golden rice can meet the requirement of vitamin A to avoid blindness, it is now confined to field trials (Ahmad, 2016; Dubock, 2014). Our poor people also suffer from other nutrient deficiencies and hence some plants and vegetables could be modified genetically to serve as a source of multiple nutrients.

The future potential of plant biotechnology includes working on genetic modification of herbal plants by modern technology to develop effective drugs, beautyceuticals and neutraceuticals, development of rapid diagnostic tools and development of post-harvest technology to minimise the loss of agricultural products and to produce stress tolerant crop varieties.

### 6.1.2 Animal Biotechnology

Animal biotechnology encompasses a broad range of techniques for the genetic improvement of animal species, animal vaccines and development of rapid test kits to diagnose the disease of livestock, poultry and companion animals. BLRI, NIB, BAU, Chittagong Veterinary and Animal Sciences University (CVASU), etc. are working to adopt modern biotechnological tools to develop livestock and poultry. Techniques of traditional biotechnology like artificial insemination and selective breeding are being practiced extensively in the country. In vitro fertilisation and embryo transfer have been carried out successfully in the laboratories and in field trial and are being used in some selective areas. Several vaccines have been developed against cattle, poultry and goat, e.g. Goat Plague (PPR), goat pox. Vaccines against anthrax, Foot and Mouth Disease (FMD), fowl cholera, Salmonella, Newcastle disease, etc. are producing by Department of Livestock Services (DLS). Work is going on the development of multivalent FMD vaccine at BLRI. Since 2007, poultry industries of the country are facing avian influenza epizootics; National Reference Laboratory for Avian Influenza at BLRI has been engaged to detect avian influenza virus subtype and molecular characterisation of the pathogen. Research on DNA fingerprinting and microsatellite genotyping methods for parentage verification and molecular characterisation of indigenous goat, sheep, cattle and buffaloes are being carried out at NIB, BAU and BLRI. Karyotyping and blood protein polymorphism of goat, sheep, cattle and buffalo are also under research in BLRI and BAU (Md. Salimullah, 2016).

### 6.1.3 Fisheries Biotechnology

Bangladesh Fisheries Research Institute (BFRI) conducts some basic Biotechnological research on seed production of endangered fish species through in vitro fertilisation, production of carps, catfishes and genetically improved farmed tilapia (GIFT) through selective breeding, production of monosex tilapia, development of hydrid variety of magur and punti, and freshwater pearl production. Besides, University of Dhaka and BAU developed the techniques for characterisation of different commercially important fish species including Hilsa through RAPD, mtDNA and RFLP techniques. No transgenic strain of fish has been produced in the country yet (Md. Salimullah, 2016). NIB has been carried out research to develop cry preservation techniques for fish sperm and disease detection.

## 6.2 Health Biotechnology

Biotechnology in health care and diagnostic services has been started and is rising day by day. There are several organisations such as International Centre for Diarrhoeal Disease Research 'Bangladesh (ICDDR,B), Bangladesh Institute of Research in Diabetic, Endocrine and Metabolic disorders (BIRDEM), and Institute of Public Health (IPH), Institute of Epidemiology, Disease Control & Research (IEDCR) and NIB are prominent among others.

Organisations are providing molecular diagnostics such as PCR, microsatellite marker-based diagnosis of tuberculosis, diarrhoea, cholera and hepatitis viruses etc. Development of Shigella vaccine is being carried out at ICDDR,B. BIRDEM is providing molecular diagnostic services like PCR of infectious diseases (tuberculosis, viral hepatitis, HIV etc.), karyotyping etc. The IPH is engaged in the production of vaccines and anti-sera. IPH has made small pox eradication program successful by producing highly potent small pox vaccines. Since 1992, the IPH has also been engaged in the production of high-quality tetanus vaccines. Recently, some private company has also been started to provide molecular diagnostic services. Incepta has signed an agreement with ICGEB, New Delhi Unit, for commercially manufacturing hepatitis B vaccine. The National Forensic DNA Profiling Laboratory at the Dhaka Medical College Hospital (DMCH) and four divisional medical college hospital made it possible the forensic tests of international standard in Bangladesh with the technique termed DNA fingerprinting to perform paternity tests, criminal dispute in cases of rape and murder etc (Md. Salimullah, 2016). NIB has been carrying out research on genetic diseases and providing DNA sequencing service.

### 6.3 Industrial Biotechnology

In the field of industrial biotechnology, Bangladesh is yet to make real breakthroughs. Modern biotechnological programmes involving gene transfer technology have yet to be started in real earnest. Mass scale production of spirulina, biofertilizer, baker's yeast, citric acid has been reached at the commercial stage. A few distilleries in the country are already utilising >50,000 MT of molasses to produce ethanol. Research is also going on enzymes, single cell protein, etc. A significant achievement has been made in the field of 'Biogas' production from cow dung and agricultural residues. The BCSIR in collaboration with Department of Energy (DOE) have installed more than 20,000 biogas plants in rural areas. An extended programme to set up about 100,000 biogas plants has also been taken up by the government.

Three new bacterial species (Rhizobium bangladeshense, Rhizobium binae, Rhizobium lentis) were discovered at the BINA, which create legumes crops and increases productivity (Md. Salimullah, 2016) which are promising for the productions of biofertilizers. Earlier Rhizobium biofertilizer production in a pilot scale at BINA had been successful and its use in pulse crops has been found to be effective in the farmer's field and the production increased about 20%. Development of rice biofertilizer is in progress at BINA, NIB, and BAU (Md. Salimullah, 2016).

To have maximum benefit from the microbes, NIB has emphasized on enzyme technology. NIB has been carrying out research for development of eco-friendly enzymes for leather (Barman et al., 2017) and textile processing from bacterial sources and development of process for generation of electricity from garbage (Barua et al., 2018; Saha et al., 2019).

They are carrying out research on emerging infectious diseases and have sequenced whole genome of Hepatitis B virus (HBV) (Shaha, Das, et al., 2018) and identified mutations in HBV genome sequences isolated in Bangladesh and the molecular evolution of HBV/C2 strain (Shaha, Chakraborty, Hossain, Hashem, & Salimullah, 2018; Shaha, Das, et al., 2018).

BAEC has employed gamma radiation to the silkworm for the enhancement of silk production. Significant progress has been achieved on sterile insect technique (SIT) by utilising gamma radiation and has developed methods for production of sterile male of Aedes mosquito. Besides, hormonal and pheromonal control of insects and the integrated pest management (IPM) programme are now being adopted for insect management. Isolation and characterisation of Bacillus Thuringiensis strains for the control of Lepidopteran insects has been initiated at the University of Dhaka (Md. Salimullah, 2016).

Sericulture Research Institute has been working for a long time for the improvement of sericulture production in Bangladesh. Recently, BCSIR Laboratories, Dhaka has been engaged in DNA barcoding research for taxonomic identification and documentation of various endemic species of insects, plants and animals including other organisms of economic importance and detection of adulteration in processed and unprocessed food products (Md. Salimullah, 2016).

Development of protocols for pathogen detection (e.g. virus and bacteria) through modern molecular techniques like DAS-ELISA, Real Time PCR, hybridisation etc. from different crops, forest, fruit, ornamental, medicinal and commonly important plants as well as vegetables are being done at BCSIR. Additionally, identification of new pathogens both from plants and animals are also being studied (Md. Salimullah, 2016).

### 6.4 Bioinformatics

Bangladesh is yet to explore and secure its place in this exciting field of biotechnology. Now, we have whole genome sequence of few organisms, it is time to explore them for the desired outcome. Modern research activities on these fields have been taken on some institutes and universities. NIB has started research in the field of functional genomics and has established a core bioinformatics facility (Md. Salimullah, 2016). Through the application of this tools, NIB has elucidated the potentials of vaccine & drugs development for Rota virus (Hossain, Hashem, Keya, & Salimullah, 2016), West Nile virus (Hossain, Keya, et al., 2018) Shigella flexneri (Hossain, Khan, et al., 2016) and A database named "CampyNIBase" created to prioritize the therapeutic targets of campylobacter bacteria for drug and vaccine design (Hossain, Omar, et al., 2018).

### 6.5 Manpower Development

Trained manpower is equally important to the proper utilisation of the results of the biotechnology and development of Biotechnology. NIB providing hands on basic training for universities graduates and advanced training for early carrier professionals within its limited capacity.

## 7. Bangladeshi Companies to Biotech products

There is no available information on the market of biotech products in Bangladesh. However, the estimated local demand of biotech drugs in Bangladesh is about BDT 600 crore. Due to the crying need of biotech products for human medicines, the pharmaceutical companies are turning to biotech and high-tech products gradually. Several companies have already introduced anti-cancer, anti-HIV/AIDS drugs, human insulin, and many other companies are planning to launch biotech and high-tech products to keep pace with the world's pharma market (Rahman, 2011).

### 7.1 Anti-cancer drugs

The estimated market of anti-cancer drugs is BDT 300 crore. At present, Beacon, Beximco, Incepta and Techno Drugs are manufacturing anti-cancer drugs. Roche (Bangladesh), Sanofi-Aventis (Bangladesh) and some other importers market anti-cancer drugs.

### 7.2 Human insulin

The value of human insulin consumption in Bangladesh is estimated as BDT 100 crore. More than 80% of insulin market is presently held by Novo Nordisk (Denmark). Recently Square, Incepta, and Popular Pharmaceuticals have started to manufacture the finished product from imported crystals insulin. In near future, it is expected that our local companies will mostly enjoy the major market share of insulin and thus will go for shelf-sufficiency of insulin demand.

### 7.3 Vaccines

The estimated market of vaccines in Bangladesh is BDT 100 crore. No company has yet been involved with vaccine manufacturing in Bangladesh; however, Incepta and Popular Pharma are going to launch vaccines in their dedicated plants soon. Few other companies like Biopharma, Beacon, and JMI Pharma are preparing to launch vaccines in near future. At present, Glaxo-SmithKline (GSK), Sanofi-Aventis (Bangladesh) Ltd. and some other importers are marketing vaccines in Bangladesh.

### 7.4 Anti-HIV/AIDS drugs

Beximco Pharmaceuticals Ltd. involved with the manufacturing of anti-HIV/AIDS drugs since the last few years. They are also preparing to launch many high-tech and biotech lifesaving drugs in its manufacturing plant in near future.

## 8. Breakthrough of Biotechnology in Bangladesh

### 8.1 Jute genome

In 2008, with the funding of the government, the University of Dhaka, DataSoft IT firm and BJRI initiated a collaborative genome research program on jute under the leadership of Dr. Maqsudul Alam and Dr. Haseena Khan and in 2010 successfully sequenced the genome of jute, through which, Bangladesh became the second country after Malaysia, among the developing nations to have successfully sequenced a plant genome (Alam, Islam, Ahmed, Haque, & Alarm, 2016; Alam et al., 2017; Islam et al., 2017; Mahmood, 2013).

### 8.2 Fungus genome

In 2012, Jute genome group decoded the genome of Macrophomina phaseolina, a Botryosphaeriaceae fungus, which is responsible for causing seedling blight, root rot, and charcoal rot of more than 500 crop and non-crop species throughout the world (Islam et al., 2012).

### 8.3 Buffalo genome

A Bangladeshi company with Beijing Genomics Institute (BGI) have jointly unravelled the complete genome of water buffalo, opening up a new horizon in developing better breeds of the animal for milk and meat (Mintoo et al., 2019).

### 8.4 Bt-Brinjal

To get relief from the pesticide residue problem and to minimise the production loss, the National Committee on Biosafety (NCB) on December 31, 2013 approved limited field release of Bt-brinjal developed by BARI through the technical support of MaHyCo, India. Bangladesh became the first country in south Asia to cultivate the GM food crop. The varieties are GM with a Cry1Ac gene from Bacillus thuringiensis (Bt), resistant to destructive insect pest of brinjal which caused up to 80% crop loss before introduction (Choudhary, Nasiruddin, & Gaur, 2014; Meherunnahar & Paul, 2009; Shelton, Hossain, Paranjape, & Azad, 2018).

## 9. Concern

As biotechnology is being used widely, questions and concerns have also been rising. The most vocal opposition has come from European countries. Main areas of concern is the safety of GM food. In Bangladesh, different organisations including NGOs are in active opposition of the GMOs. NIB is attempting to establish a wing to certify the GMOs in Bangladesh as it has been assigned by the authority.

The foods grown from GMOs may have either beneficial or occasional harmful effects on human health depending on the food itself. For example, a biotech-derived food with a higher content of vitamin is likely to have a positive effect for vitamin-deficient individuals. Alternatively, the transfer of genes from one species to another may also transfer the risk for exposure to allergens. These risks should be systematically evaluated by governing authorities and identified prior to commercialisation.

However, understanding of science and long experiences with biotech-derived plants is that no evidence is insight that genetic transfers between unrelated organisms pose human health concerns. The risks associated with biotechnology are the same as those associated with plants and microbes developed by conventional methods (Md. Salimullah, 2016).

## 10. Conclusion and Recommendations

Bangladesh is an agroeconomic country with a large population compared to its land area and resources. Our food demand is expected to be much higher than its current growth of production. Such crop production would have to be achieved in an adverse climatic condition. Therefore, there is a growing need to develop stress tolerant crop varieties to combat climate change induced disasters like flood, drought and intrusion of salinity. Improvement of fisheries & livestock, biodiversity conservation, biological and industrial waste management, health care systems, forestry and environment sectors deserve much attention. Biotechnology can play important role to address the above issues. In a changing climate, our prime need is to introduce eco-friendly biotechnological approaches to address food security and safety, biodiversity conservation and management of sustainable environment for the betterment of a healthier, cleaner and greener nation.

***Sector wise recommendations are as follows***

In the present scenario, to fulfil the fundamental needs of mass, emphasis should be given on the development of salinity tolerant crop varieties of rice, jute and other crops for costal belt, flood tolerant rice variety for flood prone area and drought tolerant crop varieties for dry season, especially for northern part of Bangladesh on urgent basis to combat with climatic change. Development of eco-friendly biofertilizers for main crops like rice and pest/insect resistant crops varieties to be another prominence to reduce environmental pollution. Genetic modification of herbal plants by modern biotechnology to develop effective drugs and neutraceuticals to be consider as priority areas. R & D activity also need to be carried out to produce vaccines in fruits and vegetables like banana and potato to develop edible vaccines to combat with common diseases. Development of post-harvest technology to minimise the loss of agricultural products to be considered effectively.

In the field of medical biotechnology, emphasises should be given on production of laboratory kits and tools, creation of DNA-based diagnostics facility for the identification of genetic and infectious diseases; genome sequencing of disease-causing microbes and pharmacogenomics programme on Bangladesh's human genome diversity for the development and validation of drug targets are crucial.

Industrial biotechnology can pour its blessings on us through production of biopolymer to serve biodegradable plastics, plant for biofuel production, biogas for electricity and biomolecules like proteins, hormones and enzymes to use in industrial and therapeutic purposes.

Industrial effluents and household waste are creating a large amount of garbage every day. Microorganisms could be used for the processing of these wastes to detoxify these or to make these less toxic to protect our environment pollution.

Finally, we need trained manpower in biotech research & development and world class infrastructures. Beside this, mass awareness on the benefit of biotechnology and on ethical & legal issues ratified and maintained by the government to be created.

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