National Sectoral Paper

Biotechnology

Farm Sector Development Department
National Bank for Agriculture and Rural Development
Mumbai

NABARD's Vision

Development Bank of the Nation for fostering rural prosperity

NABARD's Mission

Promote sustainable and equitable agriculture and rural development through participative financial and non-financial interventions, innovations, technology and institutional development for securing prosperity

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Foreword

As India's population approaches 1.5 billion, ensuring food security and meeting nutritional demands have become critical national priorities. Policymakers are increasingly turning to modern biotechnology as a strategic solution to enhance agricultural productivity, reduce environmental impact, and build resilience against climate change. Biotechnology has already demonstrated its transformative potential. For instance, Bt cotton, introduced in 2002, now covers over 90% of India's cotton acreage, contributing to a doubling of cotton yields and a significant reduction in pesticide use. However, the scope of biotechnology extends far beyond cotton. Recent breakthroughs include the development of climate-smart crops like the drought-tolerant chickpea variety SAATVIK (NC 9), which offers enhanced yields under water-stressed conditions. Similarly, genome-edited rice lines using the DEP1 gene have shown increased grain numbers and yield in greenhouse trials, offering a promising path to food grain self-sufficiency.

India's Department of Biotechnology has also launched the first-ever 90K SNP genotyping arrays—IndRA for rice and IndCA for chickpea—enabling precise DNA fingerprinting and varietal identification. These tools are vital for ensuring genetic purity and accelerating crop improvement programs. In the context of oilseed production, where India remains heavily import-dependent, biotechnology can play a pivotal role. Genetic modification technologies can help develop high-yielding, pest-resistant oilseed varieties, reducing import bills and enhancing farmer incomes.

Climate change continues to threaten agricultural stability, with erratic rainfall and rising temperatures affecting crop cycles. Biotechnology offers tailor-made solutions such as heat- and drought-tolerant crops, biocontrol agents like fungal nano-formulations for eco-friendly pest management, and nutrient-enriched crops to combat malnutrition.

The vision of a Bio 3 Economy—integrating bio-resources, biotechnology, and bio-ecology—positions India to lead in sustainable agricultural innovation. The development of the Amaranth Genomic Resource Database and NIRS-based screening for nutritional traits exemplifies how biotechnology can support both health and sustainability goals.

To fully realize these benefits, India must invest in robust R&D, streamline regulatory approvals, and foster public-private partnerships. The recent Supreme Court directive to evolve a national policy on genetically modified crops underscores the urgency of building a science-based, inclusive framework for biotech adoption In conclusion, biotechnology is not just a tool—it is a catalyst for agricultural transformation. By embracing biotechnological innovations, India can secure its food future, empower its farmers, and lead the world in climate-resilient, sustainable agriculture.

Shaji K V
Chairman
National bank for Agriculture and Rural Development
Mumbai
July 2025

Message

India's biotechnology industry stands at the forefront of innovation, growth, and global collaboration, playing a pivotal role in shaping the nation's BioEconomy. With an expected market size of Rs. 5.4 lakh crore by end of 2025, the sector is rapidly emerging as a global hub for biosimilars, biopharmaceuticals, and cutting-edge research. The Government of India has laid a strong foundation for biotech innovations in the form of 2 DBT-supported Biotech Parks and 75 BIRAC-supported bio-incubators. The National Biotechnology Development Strategy (2020–25) aims to create a unified ecosystem for innovation, skill development, and knowledge sharing.

Biotechnology also empowers farmers to adapt to climate change. Drought-tolerant, flood-resistant, and heat-resilient crop varieties are being developed to withstand extreme weather conditions. These innovations are crucial in ensuring stable food production in the face of unpredictable climate patterns.

Moreover, agricultural biotechnology supports sustainable farming by reducing the need for water, fertilizers, and pesticides. It also opens doors to biofortified crops that address malnutrition by enhancing the nutritional content of staple foods.

Animal biotechnology in India is emerging as a transformative force in improving livestock productivity, animal health, and food security. With a rich heritage in animal husbandry and one of the world's largest livestock populations, India is uniquely positioned to harness biotechnology for sustainable growth in the animal sector.

Through genetic improvement, disease diagnostics, and vaccine development, animal biotechnology is helping farmers raise healthier, more productive animals. Techniques such as artificial insemination, embryo transfer, and molecular breeding are enhancing traits like milk yield, disease resistance, and growth rates in cattle, buffalo, poultry, and other livestock.

India has made significant strides in developing indigenous vaccines and diagnostic kits for major animal diseases such as Foot and Mouth Disease (FMD), Brucellosis, and Avian Influenza. These innovations not only protect animal health but also safeguard public health by reducing the risk of zoonotic diseases. With growing demand for animal protein and dairy products, biotechnology offers sustainable solutions to meet future nutritional needs.

Agriculture biotechnology is not just about science—it's about empowering farmers, protecting animal and human health, and building a resilient agricultural economy. With continued investment, innovation, and collaboration, India can lead the way in responsible and inclusive animal biotechnology.

Dr A K Sood
Deputy Managing Director
National bank for Agriculture and Rural Development
Mumbai
July 2025

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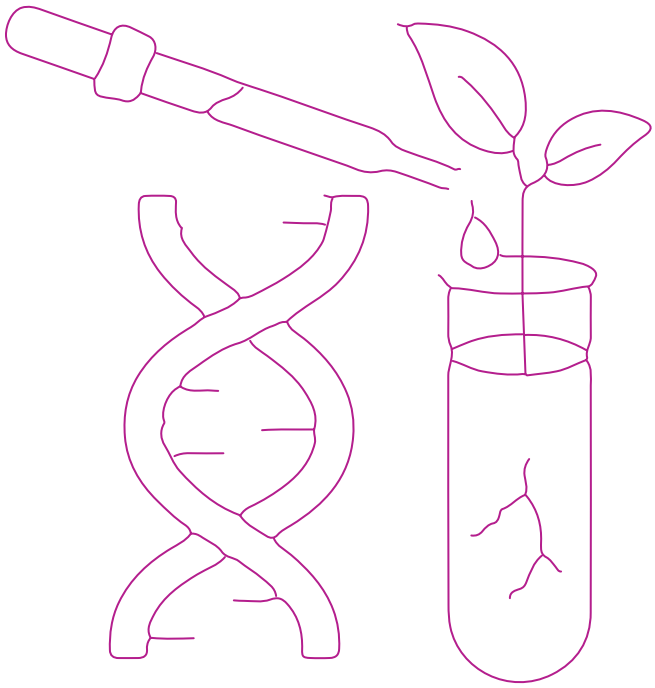


01 Introduction

1.1 Definition

Biotechnology can be defined as the use of biological science and engineering principles to manipulate biological systems, living organisms, or their derivatives, with the goal of creating or modifying products and processes. This aligns with the broader definition by the Convention on Biological Diversity (CBD), which states biotechnology encompasses any technological application involving biological systems or organisms to produce specific outcomes.

Biotechnology provides powerful tools for the sustainable development of agriculture, fisheries and forestry, as well as the food industry. When appropriately integrated with other technologies it can be of significant assistance in meeting the needs of an expanding and increasingly population. Interpreted in this broad sense, the definition of biotechnology covers many of the tools and techniques that are common in agriculture and food production. Interpreted in a narrow sense, which considers only the new DNA techniques, molecular biology and reproductive technological applications, the definition covers a range of different technologies such as gene manipulation and gene transfer, DNA fingerprinting and cloning of plants and animals.

While there is little controversy about many aspects of biotechnology and its application, genetically modified organisms (GMOs) have become the target of a very intensive and, at times, emotionally charged debate. FAO recognizes that genetic engineering has the potential to help increase production and productivity in agriculture, forestry and fisheries. It could lead to higher yields on marginal lands in countries that today cannot grow enough food to feed their people. Additionally, Chapter 16 of Agenda 21, a UN action plan for sustainable development created during the 1992 Earth Summit focuses on the Environmentally Sound Management of Biotechnology. This chapter emphasizes the responsible use of biotechnology to support sustainable development goals while minimizing potential environmental and health risks. It highlights the importance of using biotechnological advancements in ways that are safe, ethical, and supportive of biodiversity, food security, and human well-being.

1.2 Scope and Potential

In our country, the biotechnology industry can be traced back to 1980s when the Government created Department of Biotechnology. India is among the top 12 biotechnology destinations in the world and the third largest in the Asia-Pacific region. The country holds 3-5% of the global biotechnology industry pie. The country is also the world's third-largest producer of recombinant Hepatitis B vaccine and second-largest producer of BT cotton.

India's bio-economy industry has grown from US$ 8 billion in 2014 to US$ 100 billion in the last 8 years (2022). The industry at US$ 130 billion in 2024 is expected to reach US$ 300 billion by 2030. India has a strong start-up ecosystem, proof-of-concept funds for start-ups, ease of doing business, and favourable government policies. The biotechnology industry in India at US$ 130 billion in 2024 with 75 bio-incubators across 21 states/ UTs supporting has supported 1800+ incubates, 6,500 plus biotech start-ups, which are estimated to reach 10,000 by 2025. In the Indian bio-economy market, biopharmaceuticals and medical devices industry are the two largest segments, accounting for nearly 79% of the total contribution. The industry's growth is driven by vaccines and recombinant therapeutics. By 2025, the vaccination market in India is projected to be worth ₹252 billion (US$ 3.04 billion).

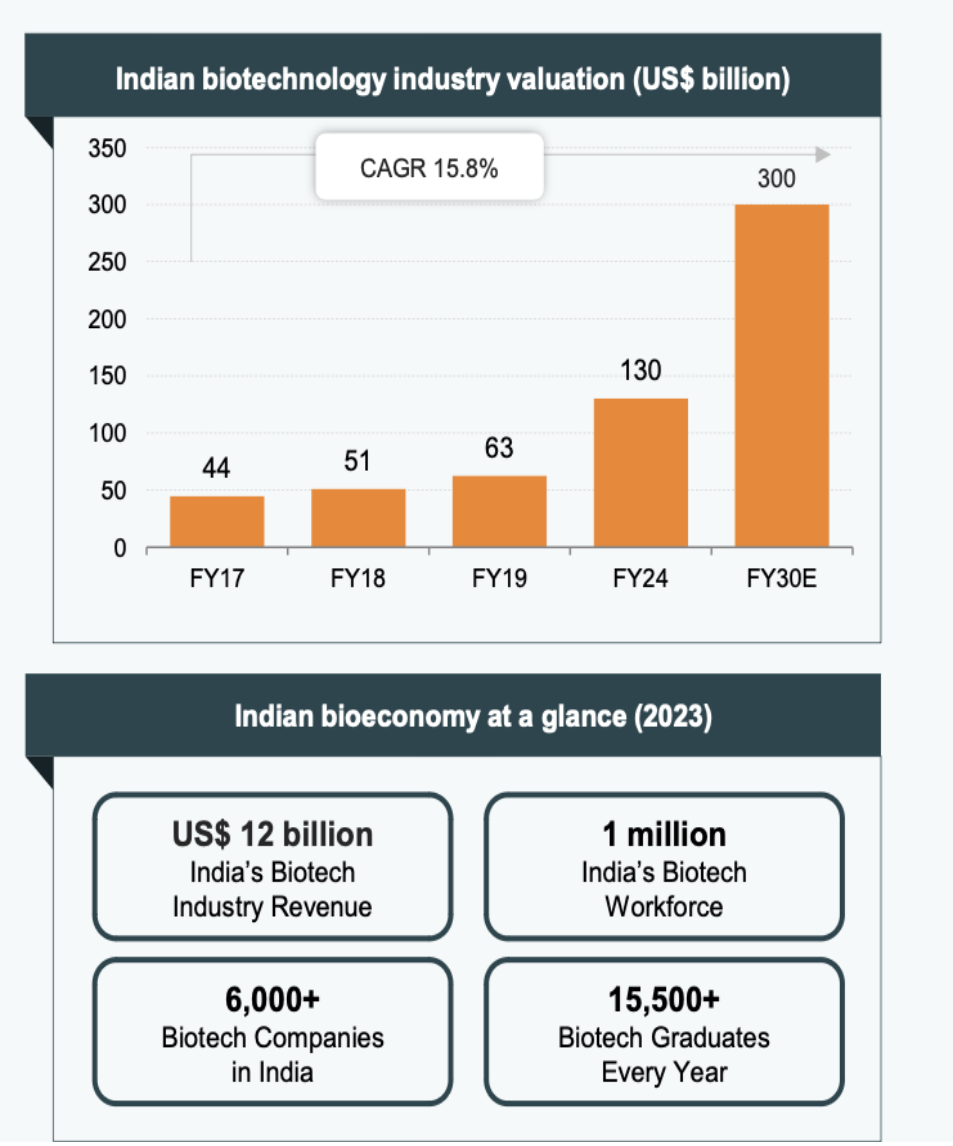
The biotechnology sector has witnessed a significant rise in new startup registrations across the nation in 2021, with approximately 1,128 fresh startups entering the market. This surge has contributed to the overall count of biotechnology startups reaching around 6,000 by the year 2023. The country is also the world's third-largest producer of recombinant Hepatitis B vaccine and second-largest producer of BT cotton (genetically modified pest-resistant plant cotton).

1.3 Advantage India

- **Skilled Human Capital:** With a total population of 1.4 billion, 47% being under the age of 25, India has a large pool of young and skilled workforce. India has a large reservoir of scientific human resources including scientists and engineers. Biotechnology has emerged as a trending career option among the youth. According to a survey of Class 12th students in Delhi, Biotechnology was ranked as the preferred stream at No.4/5.
- **Infrastructure Facilities:** 9 DBT supported biotech parks and 60 BIRAC supported bio-incubators. In February 2023, Serum Institute of India announced centre of excellence in Hyderabad to tackle future pandemics. In July 2023, 15 companies sign MoUs worth ₹2,000 crore (US$ 239.99 million), in a day, for investments in biotech sector.
- **Policy Support:** National Biopharma Mission is supporting 101 projects including more than 150 organizations and 30 MSMEs. It has increased employment opportunities and engaged 1,065 manpower including 304 scientists/ researchers. o While 74% is permitted under automatic route for brownfield projects, 100% under government route is permitted for brownfield investments.
- DPIIT and BIRC haves launched SEED fund scheme BIG schemes, respectively to young startups and entrepreneurial individuals..
- The Cabinet has endorsed the consolidation of two Department of Biotechnology schemes into 'Biotechnology Research Innovation and Entrepreneurship Development (Bio- RIDE) with a new Biomanufacturing and Biofoundry component. The allocated budget for 'Bio-RIDE' is ₹9,197 crore (US$ 1.1 billion) for 2021-22 to 2025-26 under the 15th finance commission.

1.4 Biotechnology market

The biotechnology sector in India is witnessing a strong growth trajectory and has proved to be highly inventive. The sector, mainly due to its multidisciplinary approach, holds the potential to provide an array of solutions for challenges in various sectors such as health, agriculture, environment, energy, and industrial processes. India is among the top 12 biotechnology destinations in the world and the third largest in the Asia-Pacific region. The Indian biotech industry holds about 3% of the global market share. The growth of the Indian biotechnology sector is driven by increasing demand both domestically and internationally. Initiatives like Aatmanirbhar Bharat and Make In India are key factors contributing to the rise in domestic demand. India exports vaccines to more than 150 countries and is a prime destination for contract



manufacturing and clinical trials. India's bio-economy industry has grown from US$ 10 billion in 2015 to US$ 130 billion in 2024 and is likely to reach US$ 150 billion by 2025. It has the potential to reach US$ 270-300 billion by the year 2030. By 2025, the contribution of the Indian biotechnology industry in the global biotechnology market is expected to increase to ~19%.

Cotton: A key driver of India's cotton production growth has been the widespread adoption of Bt. Cotton, the only genetically modified crop approved for commercial cultivation in India by the Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment, Forests, and Climate Change (MoEF&CC). Since its introduction in 2002-03, the area under Bt. Cotton cultivation has expanded dramatically from just 29,000 hectares (0.34% of the total cotton area) to 12.669 million hectares in 2022-23, covering 95% of the total cotton area. This widespread adoption has led to a significant increase in cotton production, which rose from 8.6 million bales in 2002-03 to 35.5 million bales in 2022-23. While Bt. Cotton has played a crucial role in boosting India's cotton production, there are ongoing challenges that need to be addressed to sustain this growth. For instance, countries like Mexico, which have higher cotton yields, have completely adopted genetically modified seeds with Bt+ herbicide-tolerant traits. To stay competitive, it is recommended that India's Ministry of Agriculture and Farmers' Welfare focus on developing early maturing and hybrid seeds that cater to the specific needs of Indian farmers. The Central Institute for Cotton Research, Nagpur, has suggested that early maturing Bt and non-Bt varieties be introduced in 20% of the cotton-growing areas where long-duration Bt hybrid seeds are currently used. Protecting these seed varieties through the Protection of Plant Varieties and Farmers' Rights Authority could also encourage greater private sector participation in their development. However, the use of certain seeds, particularly Bt cotton hybrid seeds, which are primarily produced by the private sector, has proven to be expensive for farmers. This recurring cost significantly adds to their debt burden. The Committee has recommended that farmers be financially supported to procure quality seeds and adopt best farming practices. Additionally, it suggested that the Ministry of Textiles and the Ministry of Agriculture and Farmers' Welfare consider imposing price caps on seeds and providing further impetus to seed development. The development of high-quality cotton variants, such as extra-long staple cotton, is also crucial as domestic production currently falls short of demand. The Committee has called for the creation of seeds that are tolerant to droughts and arid conditions and resistant to pests and diseases. The adoption of advanced techniques like drip fertigation (the use of fertilizers in drip irrigation systems) is also recommended. The Committee has emphasized the importance of partnering with the private sector in all aspects of cotton development as a viable option for driving future growth. The BioEconomy value of Cotton is estimated at $9.8 billion.

Biofertilizers: The biofertilizer market in India was valued at approximately ₹1,500-₹2,000 crore (USD 200-270 million) in 2023. Biofertilizers market is

growing at a CAGR of 10-12%, driven by increasing demand for organic food and government initiatives promoting sustainable agriculture. The biopesticide market in India was valued at around ₹1,000-₹1,500 crore (USD 130-200 million) in 2023. The market is growing at a CAGR of 15-20%, fuelled by rising awareness of the harmful effects of chemical pesticides and the need for residue-free agricultural produce.

Stress-resistant crops: The market for drought and stress-resistant crops in India is valued at approximately ₹5,000-₹7,000 crore (USD 650-900 million) and is growing rapidly due to climate change, government support, and farmer demand. These crops are essential for ensuring food security, improving farmer livelihoods, and promoting sustainable agriculture. However, addressing challenges like high seed costs, limited awareness, and regulatory hurdles will be crucial for realizing the full potential of this sector. With continued investment in R&D and policy support, drought and stress-resistant crops will play a pivotal role in transforming Indian agriculture into a more resilient and sustainable system.

Biofortified crops: Towards nutritional enhancement, biofortified crops, such as iron-rich rice and zinc-enriched wheat, are being developed to address malnutrition. The market for biofortified crops in India is valued at approximately ₹1,000-₹1,500 crore (USD 130-200 million) and is growing rapidly due to increasing awareness of malnutrition, government support, and farmer adoption. These crops are essential for addressing hidden hunger, improving farmer livelihoods, and promoting sustainable agriculture.

Industrial Biotechnology: Industrial biotechnology focuses on using biological systems for manufacturing and processing. It is a rapidly growing sector in India with immense potential to contribute to economic growth, sustainability, and innovation. With a current market size of ₹10,000-₹12,000 crore (USD 1.3-1.6 billion) and a growth rate of 15-20%, the sector is poised for significant expansion.

Biofuels: India is investing in biofuels like ethanol and biodiesel to reduce dependence on fossil fuels and curb pollution. The biofuels segment is one of the largest in industrial biotechnology, valued at around ₹5,000-₹6,000 crore (USD 650-800 million). India is focusing on ethanol production from sugarcane and agricultural waste to meet its target of 20% ethanol blending in petrol by 2025.

Enzymes, Biocatalysts and Bioplastics: The industrial enzymes market in India is valued at approximately ₹2,000-₹2,500 crore (USD 260-330 million). Enzymes produced through biotechnology are used in industries like textiles, detergents, and food processing. The bioplastics market in India is still in its nascent stage, valued at around ₹500-₹700 crore (USD 65-90 million).

Waste Management: Microorganisms are being used for bioremediation and waste treatment, addressing environmental pollution. The waste management and bioremediation segment is valued at approximately ₹1,000-₹1,500 crore (USD 130-200 million).

Environmental Biotechnology: Biotechnology plays a crucial role in addressing environmental challenges. Bioremediation, where microbes are used

to clean up oil spills, heavy metals, and other pollutants; Carbon Sequestration where biological methods are deployed to capturing and storing carbon dioxide are the areas where research is going on. The combined market size of bioremediation, carbon sequestration, and biodiversity conservation in India is approximately ₹3,500-₹5,200 crore (USD 460-680 million).

1.5 Future Prospects

The future of biotechnology in India looks promising, with several trends shaping its growth. It includes precision medicine with advances in genomics and AI that will enable tailored treatments for individuals. Synthetic Biology that involves designing and engineering biological systems for new applications in healthcare, agriculture, and industry are the upcoming areas that requires global collaboration and partnerships to come out with commercial solutions.

02 Applications of Biotechnology

2.1 Agricultural Biotechnology

Agriculture Biotechnology comprises uses a range of tools and techniques - both traditional techniques as also modern techniques of genetic engineering. The science can be effectively used to provide specific solutions to problems faced by the farmers especially in the sphere of climate change, degradation of farmlands, increased soil salinity, more frequent droughts, heat waves etc. Through modern biotechnology research, scientists have identified specific genes that can be used for overcoming the challenge of abiotic (resistance to drought salinity, high temperature) and biotic (resistance to pests and diseases) stress.

Micropropagation or tissue culture: Through this a large number of disease-free quality planting material are produced in a shorter span of time without any seasonality constraints. The focus of the plant tissue culture companies is mainly in floriculture sector, banana and sugarcane. The growth in demand for tissue culture banana is expected to increase along with that of sugarcane due to ethanol blending with petrol. The demand for tissue culture plants for tuber crops e.g., potatoes, turmeric and ginger is increasing owing to enhanced farmers awareness. It is projected that in India, the tissue culture Industry is growing at a rate of 20 to 25 % per annum (Plant tissue culture Industry in India, Sheetal Dogra, International Journal of Advance Biochemistry Research, IJABR 2023; SP-7(1): 28-33).

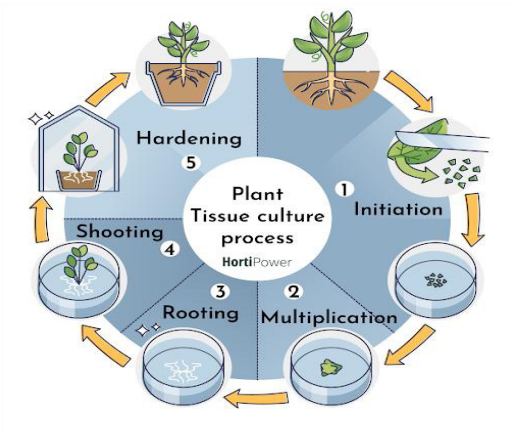
The GoI has established the National Certification System for Tissue Culture Raised Plants (NCS- TCP) authorizing Department of Biotechnology, Ministry of Science & Technology as the Certification Agency vide the Gazette Notification dated 10th March 2006 under the Seeds Act, 1966 for ensuring production and distribution of quality tissue culture planting materials. At national level, apart from many tiny units, there are many smaller units with 0.2 to 0.5 million plant production capacities. There are about 100 commercial plant tissue culture units with a minimum production capacity of about 1 million plants per year including around 20 units with installed capacity of above 5 million plants per annum (PPA). Most of these tissue culture units are in Maharashtra, Andhra Pradesh, Karnataka and Kerala. The demand for quality, true to type plantlets is increasing both for domestic and export market. This indicates the need to set up additional units and supply plants to local markets with more competitive prices for

improving the agricultural productivity and benefiting farmers.

To encourage the tissue culture industry, various central and state governments have come out with several schemes with incentives. It includes support under MIDH, SFAC & APEDA. The Government of India has identified micro-propagation (tissue culture) industry as a priority area for further research, development and commercialization. NABARD has identified it as a thrust area for extending refinance. The activity is also covered for subsidy support to trained agri-preneurs under ACABC Scheme. There is MIDH assistance for new Tissue Culture (TC) units along with assistance for rehabilitation/ strengthening of existing TC Units.

Modern plant breeding: Modern plant breeding uses techniques of molecular biology to select, or in the case of genetic modification, to insert, desirable traits into plants. Molecular biology techniques for selective crossing of two parent plants for desired traits can be used with the advantage of reduction in time when compared to traditional plant breeding techniques. Genome sequencing and genomic studies for identification of useful genes can be undertaken within the country with standardized Hi tech research through mapping and Marker Assisted Selection (MAS).

Source:https://www.corteva.com/our-impact/



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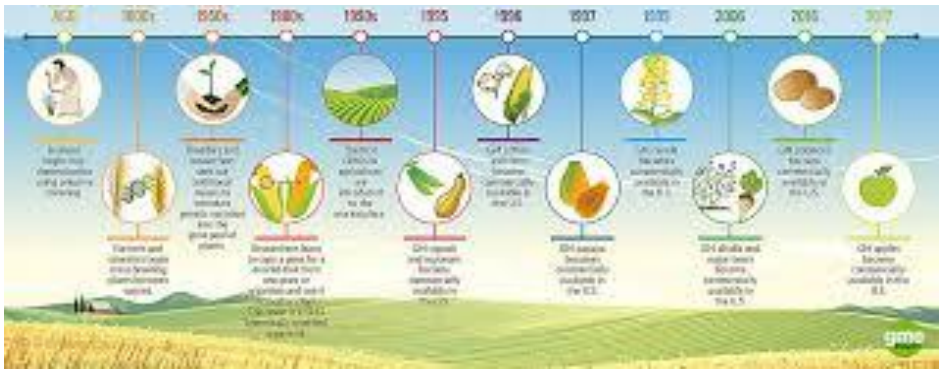
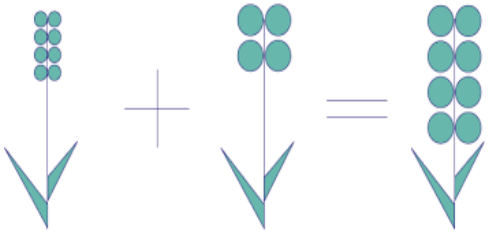


Genetic modification: Genetic modification (GM) of plants is achieved by adding a specific gene or genes to a plant, or by knocking out a gene through specialised tools, to produce a desirable trait. The plants resulting from adding a gene are often referred to as transgenic plants. Genetic modification can produce a plant with the desired trait or traits faster than classical breeding because the majority of the plant's genome is not altered.



India is among the top 5 countries growing GM crops (Bt Cotton)

GM Crop Regulation: Genetic Engineering Appraisal Committee (GEAC) monitors commercial release of GM crops in India. The GM crop regulation is under the MOEF&CC whereby the following committee overlook the regulatory aspects: (i) GEAC (ii) Recombinant DNA Advisory Committee (RDAC) (iii) Institutional Biosafety Committee (IBSC) (iv) Review Committee on Genetic Manipulation (RCGM) (v) State Biotechnology Review Committee (SBRC)

The majority of commercially released transgenic plants, are for insect/ pest resistance achieved through incorporation of a gene from Bacillus thuringiensis (Bt) that encodes a protein, toxic to some insects. For example, cotton bollworm pest, once it feeds on Bt cotton it will ingest the toxin and die. Genetic modification of plants that can produce pharmaceuticals (and industrial chemicals), sometimes called pharmacrops, is a rather radical new area of plant breeding, which is fast developing. In India, 90% of total cotton acreage is BT Cotton. Bt cotton has had a profound impact on Indian agriculture, particularly in the cotton farming sector. Its introduction in 2002 brought hope to millions of farmers by offering an effective solution to the bollworm problem. Our nation was a net importer of cotton in the 1990s, after introduction of Bt cotton in 2002, we have emerged as a leading nation exporting cotton in the world, indicating signi¬ficant productivity gains. However, the challenges that have emerged over time, including pest resistance and the rising cost of seeds, have highlighted the limitations of relying solely on GM technology for pest management. (Source: Krishak Jagat Oct 2024).

Bt cotton, short for Bacillus thuringiensis cotton, is a genetically modified organism (GMO) developed by incorporating genes from the bacterium Bacillus thuringiensis. The development of Bt cotton was a breakthrough in agricultural biotechnology and was first commercialized in the United States by the company Monsanto in 1996. In India Bt cotton was introduced in 2002 by Monsanto, in collaboration with the Indian seed company Mahyco (Maharashtra Hybrid Seeds Company). The Genetic Engineering Appraisal Committee (GEAC) of India approved commercial cultivation of Bt cotton, making it the first GM crop for cultivation in the country. Approval came after stringent process of field trials, conducted in various states. Bt cotton can significantly reduce the use of chemical pesticides. The approval of Bt cotton was seen as a major step for modernizing Indian agriculture, which promised increased yields, reduced input costs, and better resistance to pests such as bollworm. India, being one of the world's largest cotton producers has gained significantly from Biotechnology. Area under BT Cotton is over 117 lakh hectare as on 2020 (MOAFW).

In India, the GM crop research is focused on many crops, and it includes a few notable ones, such as rice, maize, cotton, citrus, coffee, chickpea. Some of the major on- going programmes in India related to Agriculture Biotechnology program include Wheat Genome Sequencing Programme, Rice Functional Genomics, Crop Biofortification and quality improvement programme, Programme on Chickpea Genomics, Mustard, Marker Assisted Breeding of Rice with major QTLs for drought, flood and salt tolerance, root development and nutrition, germination etc. In addition, genes for enhanced Water Use Efficiency (WUE) in rice, will bring in climate resilience - through crop improvement programme the important traits for high yielding varieties of rice, wheat, chickpea, soybean, cotton, mustard and maize hold promise for farmers facing climate change challenges. Biotech crops may provide enhanced quality traits such as increased levels of beta-carotene in rice to aid in reducing vitamin A deficiencies and improved oil compositions in canola, soybean, and corn. Approval for biotech mustard indigenously developed by University of Delhi, chickpea and pigeon pea developed by ICAR-Indian Institute of Pulses Research are still pending. Except for Bt cotton no GM crop has been allowed for commercial cultivation in India

Crops with drought tolerance trait can provide relief to farmers facing acute climate events, maize that can grow under such stress with significant yield increase of 150% have been adopted by farmers in some countries such as Ghana. GM crop, BT Brinjal (Solanum melongena) four varieties expressing Cry1Ac to protect from fruit and shoot borer, is being grown in neighbouring nation of Bangladesh, which became the first developing country to grow GM Food Crop. The BT Brinjal was released after field testing in 2014 by Bangladesh (Source: Cold Spring Harbour Perspectives in Biology; 2019 Oct;11(10).

Biotechnological interventions in the Medicinal and aromatic plants: MAPs are known to produce secondary metabolites that find uses as flavouring agents, fragrances, insecticides, dyes and drugs. Biotechnology helps for enhancing secondary metabolism in medicinal plants which can be altered in innovative ways - to secrete phytochemicals of interest, to reduce the content of toxic compounds or even to produce novel chemicals. Through molecular biology production of secondary metabolites; plant tissue culture; DNA fingerprinting and barcoding for plant authentication purpose and biodiversity management and genetic improvement through gene, DNA and tissue banking is being undertaken which holds promise of climate resilient farming. Cultivation of new varieties of medicinal plants- lemongrass, citronella, vetiver etc is available as new crops for farmers.

Mustard is predominantly a self-pollinating crop; a robust pollination control system is required that would facilitate cross-pollination to help develop hybrids between any two selected diverse parental lines. Such a system has been developed by the Centre for Genetic Manipulation in Cop Plants, University of Delhi, which used three transgenes – barnase, barstar, and bar (bar gene confers resistance to herbicide Basta and is needed for selecting the transformed lines). Presently although the technology is available there are protests from civil society organisations with safety

Gene editing: One of the most notable advancements has been in the realm of gene editing. Researchers are increasingly leveraging CRISPR/Cas9 and other advanced molecular tools to develop crop varieties that are more resilient to environmental stresses. For instance, efforts are underway to create drought-tolerant rice and heat-resistant wheat varieties—innovations that are crucial as erratic weather patterns become the new norm. These breakthroughs not only aim to stabilize yields in adverse conditions but also contribute to reducing reliance on chemical inputs, thereby promoting eco-friendly farming practices.

Agrobiodiversity and germplasm conservation: Our nation is richly blessed with diverse biodiversity. While modern agriculture embraces most technologically advanced and efficient farming and production systems, dependent on bred or engineered crops with very restricted set of species, there is a felt need that the great diversity ranging from locally cultivated species or semi-domesticated in-home gardens or harvested from the wild can make a major and essential contribution to food security. It also provides for diverse set of gene pool that can be tapped to understand disease resistance and in climate adaptation. It is therefore essential to conserve biodiversity-

based agriculture through in vitro and cryopreservation means also.

Biochar Initiatives: In a recent development, Google has partnered with Indian firm Varaha to purchase carbon credits derived from converting agricultural waste into biochar. Biochar is produced by heating organic agricultural and forestry waste, such as rice husks and sawdust, in a process called pyrolysis. This process absorbs and sequesters CO2, resulting in a negative carbon effect. This initiative not only sequesters carbon but also enhances soil health, exemplifying innovative applications of biotechnology in sustainable agriculture. Google has committed to purchasing 100,000 tons of carbon dioxide removal credits from Varaha by 2030. This agreement represents the largest biochar-based carbon removal transaction in history (https://yourstory.com/2025/01/google-varaha-biochar-carbon-removal-india).

Public Acceptance for GM Food: The first U.S Food and Drug Administration (FDA) approved GM food crop viz. FlavrSavr Tomato was available in the market in 1994. This tomato had a new gene that prevented the breakdown of the tomato's cell walls, thus extending its shelf life. Although there was no scientific concern over its safety, the tomato was removed from the market in 1998 due to consumer concerns. Globally cotton, corn and soybeans are the most common genetically engineered crops, about 80 to 95% of these crops grown are GM crops. The public acceptance of GM crops is a concern worldwide. However, more than 30 countries have approved cultivation of GM crops, including India, since it was introduced in 1996. Farmers have widely adopted GM technology with the acreage increase from 1.7 million hectares in 1996 to 206.3 million hectares in 2023 (Global GM crop review, 2024).

The way ahead:

- The policy makers aim to achieve the goal of food security and nutritional requirements for a growing population by using best available technology and scientific inputs that are beneficial to farmers and safe for environment & human health. Hence the use of modern biotechnology is essential for adoption for improved productivity of major crops and self-sufficiency in oilseed production through yield-enhancing and price-reducing genetic modification crop technologies.
- Climate action calls for providing inputs towards R & D to make available tailor-made solutions to farming community which is increasingly facing the challenge of climate change.
- The capacity building needs of functionaries in the science-extension departments/SAUs as also the farmers/FPOs will go a long way to benefit from the ongoing development under biotechnology and pave way to adopt to newer practices with acceptability for modern technological innovations and breakthroughs.

2.2 Bio-pesticide/ Bio-fertilizers/ Vermicomposting

Intensive farming practices with chemical fertilizers usage resulting in higher cost of production and environmental/health issues makes the case of using natural inputs and hence in creating awareness for sustainable agricultural practices. Bio-fertilizers use living microorganisms

that establishes symbiotic relationships with the plants or are an inoculation of microorganisms which promotes the plant growth by increasing the primary nutrient supply to the host plant and also retains the soil fertility. Biopesticides and botanicals are certain types of pesticides derived from natural materials like plants and microorganisms. These measures are the natural choices towards organic and natural farming practices. The term vermiculture mainly refers to the scientific process of cultivating worm or artificial rearing of worms to decompose organic food wastes into a nutrient-rich material. The output of vermiculture is called vermicompost and is formed by the process in which earthworms consume the farmyard manure and roughages in addition to the wastes from farms and thereby producing it. The produced vermicompost is rich in terms of nutrients and other plant growth-promoting substances, which is capable of supplying necessary mineral nutrients to help and sustain plants growth. Vermicompost, or vermiculture, most often uses two species of worms: Red Wigglers (Eisenia foetida) or Eudrilus eugenae found in soil and are adapted to the special conditions in rotting vegetation, compost and manure piles.

The support from Government.

A number of Government programmes – Central as well as State, are currently promoting organic and natural farming. A few NABARD supported Farmers Producer Organisations also promote Organic farming. Ongoing Government initiatives/ programmes in this field are indicated as under.

- To promote the use of bio pesticides in agriculture, Central Insecticide Board & Registration Committee has formulated simplified guidelines for registration of bio pesticides as compared to chemical pesticides. During provisional registration granted under Section 9 (3B) of the Insecticides Act, 1968, the applicant is allowed to commercialize the bio-pesticides, unlike chemical pesticides.
- Government of India through organic farming schemes of Paramparagat Krishi Vikas Yojana (PKVY), Mission Organic Value Chain Development for Northeastern Region (MOVCDNER) and Capital Investment Subsidy Scheme (CISS) aims for sustainable agriculture production with eco-friendly process in tune with nature, promoting organic inputs and chemical free agriculture produce for improving the health condition of the people. Under, Paramparagat Krishi Vikas Yojana (PKVY), assistance of ₹50,000 per hectare for 3 years is provided, out of which ₹31,000 (62%) is given to the farmers directly through DBT, for inputs (bio-fertilizers, bio-pesticides, vermicompost, botanical extracts, etc.) production/ procurement, post-harvest management etc.
- Under Mission Organic Value Chain Development for Northeastern Region (MOVCDNER), the farmers are given assistance of ₹25000 per hectare for 3 years for both on-farm & off-farm organic inputs, and seeds/ planting material.
- Under, Capital Investment Subsidy Scheme, Government of India promotes production of bio-fertilizers by providing 100% assistance to

State Government / Government Agencies upto a maximum limit of ₹160.00 lakh/ unit for setting up of state of art liquid/ carrier-based Bio-fertilizer units of 200 Tonnes Per Annum capacity. Similarly, for individuals/ private agencies assistance upto 25% of cost limited to ₹40 lakh/unit as capital investment is provided through National Bank for Agriculture and Rural Development.

- With the increasing awareness of organic farming, Government is promoting the use of Organic manures under the scheme PKVY of National Mission for Sustainable Agriculture (NMSA), through assistance (i) under the component Integrated Manure Management of Paramparagat Krishi Vikas Yojana (PKVY) for Phosphate Rich Organic Manure (PROM) as per specification given in FCO, 1985 @ ₹1000/acre for procuring and application of PROM to soil to meet phosphorus/ Zinc deficiency in soil (ii) financial assistance for vermi-compost (size 7'x3'x1') @ ₹5,000/- unit for procurement of earth worms, preparation of pits, construction of brick wall etc. (iii) promotion of organic inputs under Organic & INM Components of Soil Health Management, assistance is provided for vermi-compost, Bio-fertilizers (Liquid / solid), Waste compost, Herbal extracts etc. including PROM @ 50 % of cost subject to a limit of ₹5000/- per ha and maximum ₹10,000 per beneficiary.
- Under the Rain fed Area Development (RAD) component of NMSA, 50% of cost subject to limit of ₹125/- per cubic ft. and maximum permissible assistance of ₹50,000/- per unit for permanent structure and ₹8,000/- per unit for High Density Polyethylene (HDPE) vermi bed is provided for construction of compost unit and, organic input production unit.

2.3 Animal Biotechnology

India is the largest animal husbandry sector in the world with largest livestock population to support the livelihoods of more than two-thirds of the rural population, mainly small and marginal farmers. Livestock can sustain the food demands of the rural households and also provides stability at the time of crop failures. Therefore, sustainable animal production and health is important as healthy animals are closely related to healthy people and healthy environment. The 20th Livestock Census in India, conducted in 2019, reported a total livestock population of 536.76 million, reflecting a 4.8% increase from 2012. Bovine Population increased by 1.3% and growth in sheep, goats and poultry was more than 10% and pig population declined by 12%. The livestock sector has shown robust growth, with a Compound Annual Growth Rate (CAGR) of almost 8% for dairy and 10% for Sheep and goat.

India's livestock exports have been growing, particularly in the meat and dairy sectors. The country is a significant player in the global market for Buffalo meat and dairy products. With proper management, livestock can enhance biodiversity, improve soil health through manure, and contribute to carbon sequestration.

According to PIB document, a study has shown that Farming households with livestock will be able to better withstand

distress caused due to extreme weather conditions and crop failures. . It is reported that there were no suicides in families of farmers who diversified into allied activities like poultry, dairy or aquaculture.

Livestock and Animal Biotechnology Increasing land degradation, global warming, erosion of animal and plant genetic resources, severe water shortages and the threat of emerging infectious diseases pose several new challenges to sustainable animal production, particularly in developing countries. Currently, fast population growth and the associated increase in the demand for livestock products present many development opportunities and growing challenges. The key challenge is determining how to intensify livestock productivity in a sustainable manner to meet the increasing demand under the constraints of limited land, water and other natural resources. Current advancements in science and technology will have an important role to play in promoting the livestock sector.

Biotechnology has the potential to improve the productivity of animals via increase in milk yield, egg production, growth, carcass quality & reproduction, improved nutrition & feed utilization, improved quality & safety of food, improved health & welfare of animals and reduced waste through more efficient utilization of resources. Therefore, the biotechnology of livestock production is growing faster than any other sectors; and by 2030, livestock is predicted to become the most important agricultural sector in terms of value-added commodity. The application of biotechnology in production of animal is a need and must meet the worldwide demand as well as for the genetic improvement in the animal diversity.

The term “Animal biotechnology” is defined as the application of scientific and engineering principles to the processing or production of materials by animals or aquatic species to provide goods and services for the wellbeing of human population. Biotechnology has been practiced since the beginning of animal husbandry. The evaluation and selection of different breeds started with the domestication of animal species around 12000 years ago which was led by the wish to obtain traits dictated by social, nutritional and environmental needs with no understanding of the molecular processes involved. The various biotechnological applications in animal production are being discussed in the subsequent paragraphs.

Animal reproduction, genetics and breeding: The main objectives of using reproductive biotechnologies in livestock are to increase production, reproductive efficiency and rates of genetic improvement. Over the years, many options have become available for managing the reproduction of the major large and small ruminants. Artificial insemination (AI) and preservation of semen are the main technologies that are used extensively. Reproductive technologies can also be used to control reproductive diseases if procedures and protocols are accurately followed.

Embryo transfer: One of the major reproductive technologies that can facilitate genetic improvement in cattle is ET. Embryo transfer is a hormonal manipulation of the reproductive cycle of the cow, inducing multiple ovulations, coupled with AI, embryo collection, and embryo transfer to obtain multiple

offspring from genetically superior females, by transferring their embryos into recipients of lesser genetic merit. The high genetic merit embryos can be frozen for later transfer or sale. Most dairy farmers who use embryo transfer simply want more heifer calves from their best cows. The effect of this use of embryo transfer is to increase the selection intensity of dams to produce herd replacements. The main potential advantage of Embryo transfer for developing countries is that the elite females of local breeds can be identified, and bulls can be produced from them for use in a field programme of breed improvement.

Semen and Embryo sexing: Although these biotechnologies do not dramatically increase the rate of genetic gain, they can increase production efficiency. They are being developed and refined in a number of research institutions. Sexed semen is available in several states of India to produce more female progenies for improving the productivity of the livestock farming. NDDB Dairy Services, a subsidiary of the National Dairy Development Board has successfully conducted field trials of sex sorted semen through which the animal delivers only female calf. Currently, only two companies across the globe manufacture sex sorted semen doses. The technology is completely developed indigenously under the research collaboration with Bangalore based bioengineering player Jiva sciences Pvt. Ltd along with the Indian Institute of Science, Bangalore the Indian Institute of Technology, Chennai and the National Center for Biological Sciences, Bangalore to make it efficient and affordable.

In vitro fertilization (IVF): Unfertilized eggs (oocytes) from ovaries of live donor animals are gathered by a technique referred to as “ovum pickup”. The oocytes are matured in an incubator then fertilized with sperm. The resulting zygotes are incubated in the laboratory to the blastocyst stage. The fertilized embryos can be transferred fresh or can be frozen. Sexed semen can be used to obtain embryos of the desired sex, which is more efficient and less complicated than the Y chromosome probe-based approach.

Cryopreservation: Many livestock breeds are at risk of extinction. Semen and embryo cryopreservation have been used for conserving rare livestock breeds. Cryopreservation of gametes, embryos, DNA or cells (for example skin fibroblasts) is a cost-effective approach for the conservation of endangered species, although using DNA or non-germ cells to regenerate an extinct breed is still problematic with available technologies. It has been suggested that cryo-preserved cells of each breed should be stored long-term in secured locations and accessed if and when the need arises in the future, either to sequence their DNA to understand genetic differences among breeds or to use the cells in cloning to regenerate extinct breeds.

Cloning/Nuclear transfer: Cloning is a powerful technique and potentially opportunity to utilize the genetic contribution of both it could be used for multiplication of elite animals and minimize the genetic variation in experimental animals. It can be used for the conservation as well as propagation of endangered species. It may be used as a tool to produce stem cells for therapeutic purposes, as therapeutic

cloning. Cloning using somatic cells offers opportunities to select and multiply animals of specific merits. Numerous types of somatic cells are used as donors in somatic cloning: foetal fibroblasts, adult fibroblasts, granulosa cells, hepatocytes, lymphocytes etc. First animal obtained by somatic cloning was a sheep, "Dolly". Since then, SCNT was used successfully for cloning cattle, buffalo, pig, goat and horse. Cloning procedure using embryonic stem cells (ESCs) is called Nuclear Transfer-derived Embryonic Stem Cell (NTESC). However, although ESCs were derived for humans and some laboratory animals, derivation of farm animal embryonic stem cells (faESCs) is still unsuccessful. The alternative to faESCs could be embryonic germ cells (EGCs) and spermatogonia stem cells. Cloning holds the promise of bypassing conventional breeding procedures to allow creation of thousands of precise duplicates of genetically engineered animals. In remote areas, where sampling and storage of adequate samples of semen and embryos is not practical, one could use clone samples from diverse animals for conservation of the available genetic diversity. The local breeds may contain valuable genes that confer adaptation, especially to heat tolerance or disease resistance, and there is an urgent need to prevent their extinction, which can be achieved by cloning techniques. In the future, cloning may be used in xenotransplantation, as it would allow multiplication of humanized pigs, the organs of which could be transplanted to humans.

Globally the application of assisted reproductive technologies has been acclaimed as rapid and practically feasible for multiplication of superior germplasm. Among the several technologies, animal cloning can play a key role in faster multiplying elite animals and the conservation of endangered breeds. Gir, a native brief of Gujarat is popular among the dairy farmers because of its docile nature and good quality of milk. Gir cattle are very hardy and well known for their tolerance to conditions of stress and resistance to various tropical diseases. Scientists at ICAR-NDRI have successfully cloned a Gir cow with the help of assisted reproductive technology. CIRB, Hisar has cloned buffaloes, NRC Equines have cloned foals, The cloning technique has been successfully demonstrated for cloning the Elite as well as Endangered animals. Several SAUs also cloned animals in India.

Genome Selection Chips: Unified Genomic Chip' – 'Gau' chip for cattle and 'Mahish' chip for buffaloes. These SNP chips designed for genomic profiling and evaluation of Indian cattle breeds, have been developed by a consortium comprising of BAIF Development Research Foundation, National Institute of Animal Biotechnology and the ICAR-National Bureau of Animal Genetic Resources and led by the National Dairy Development Board. Each participating organization pooled their genome sequence and genotype data to facilitate the development of these genomic techniques. This advanced technology has enabled the direct application of DNA technologies to enhance the genetic potential of diverse dairy animal populations in the country. These chips will help farmers to identify young, superior quality bulls at an early age for selection and boost livestock productivity.

Transgenesis: Since the initial demonstration in 1980s that a transgenic animal can be generated harbouring a transgene from a different species, genetic engineering has revolutionized all aspects of fundamental biological and biomedical research. Since then, much has been accomplished in the generation of various types of first transgenic animals like mouse, pig, sheep, goat and cattle. Several biotechnological techniques, such as pro-nuclear microinjection, cytoplasmic microinjection, and retrovirus-based vectors, transferring DNA to embryos or embryonic stem cells via retroviral vectors, sperm mediated gene transfer of lentivectors and RNA interference, are presently being used to produce transgenic animals. Transgenic farm animals can be used in both breeding and biomedicine. In breeding, transgenic individuals produced are equipped with disease resistance and improved quantitative and qualitative traits. For example, transgenic cows producing milk of increased fatcontent, pigs with high body weight gain or fat to muscle tissue, expressing human growth hormone and human haemoglobin, sheep with integrated keratin-IGF-I gene and higher production of wool, sheep and goat with antithrombin III and alpha in milk. An important achievement was production of transgenic cows resistant to mastitis. There is a high interest in using transgenic farm animals as bioreactors producing human recombinant proteins in mammary gland. Transgenic domestic pigs are used in studies on xenotransplants, i.e. transplantation of animal body parts into humans. The transgenic embryo production has been initiated in India and transgenic and genome edited embryos are produced at NDRI.

Molecular markers: Marker assisted selection can accelerate the rate of genetic progress by enhancing the accuracy of selection and by reducing the time to gather the data needed for selection. The benefit is greatest for traits with low heritability, and which are unavailable before sexual maturity or without sacrificing the animal. However, in the low-input systems existing in many developing countries it may be more difficult to realize the full value of marker information because the phenotypic and pedigree information necessary to determine associations between traits and markers is often not available. ILRI's programmes focus on the characterization of local poultry in Cambodia, Laos, Vietnam, Egypt, Ethiopia, Kenya and Uganda and on small ruminants from seven countries. At ILRI, work is also underway on marker identification for trypano-tolerance. The identification and subsequent use of markers for trypano-tolerance and helminth resistance would enhance prospects of breeding for such traits. The International Bovine Hap Map project included two African breeds considered to be resistant to trypanosomosis. Opportunities to increase disease resistance seem particularly promising but uptake in developing countries is likely to be achieved only in the medium to long term rather than in the near future. Marker/gene-assisted selection has been applied in the Awassi and Assaf dairy breeds for the introgression of the Booroola gene for enhancing prolificacy. In developing countries, genotype information is expected to be initially more useful in marker/gene-assisted introgression rather than in selection within breeds. The booroola fecundity introgression programme has

been operational in India, CSWRI has produced a breed with high twinning potential “Avishaan”, In deccani breed Nimbkar Agricultural Institute has been doing the same for long time. Recently, the introgression programme has been used in TN and produced Nilagiri synthc breeds. The booroola fecundity gene has been reported in three Indian breeds namely Garole from west Bengal, Kendrapada from Orissa and Nilagiri from TN. The origin of the Booroola gene is Garole breed of WB.

National GeneBank: ICAR-NBAGR has established a National GeneBank, where genetic biodiversity of indigenous farm animals represented by a broad spectrum of native breeds of different species are cryo conserved in the form of sperms, somatic cells, DNA etc. The stored genetic material will not only help in recreating a lost breed in future but also help breeders to utilize a wide range of production environments and develop diverse products to meet the needs of local communities.

Cattle Genomic Chip: “IndiGau’, India’s first Cattle Genomic Chip for the conservation of pure breeds of indigenous cattle breeds like Gir, Kankrej, Sahiwal, Ongole etc. IndiGau is purely indigenous and the largest cattle chip of the world with 11,496 markers.

Biotechnologies in animal nutrition and production

In animal nutrition, the biotechnology can improve the plane of nutrition through protection of protein, amino acids and fat, use of enzymes to improve the availability of nutrients from feed and to reduce the wastage of the feed and fodder, prebiotics and probiotics or immune supplements to inhibit enteric pathogenic bacteria, use of plant biotechnology to produce feed and fodder with good nutritive values can be done with ease, addition of vaccines or antibodies in feeds can be used to protect the animals from the disease, and genetic manipulation of rumen microbes to improve animal health.

Amino acids: The amino acids in feed, L-lysine, L-threonine, L-tryptophan and DL-methionine constitute the largest share of the total amino acids. Amino acids are mostly produced by microbial fermentation and in the world market for fermentation products, after ethanol and antibiotics, amino acids are the most important category and demand for them is increasing rapidly. Most grain-based livestock feeds are deficient in essential amino acids such as lysine, methionine and tryptophan and for high producing monogastric animals (pigs and poultry) these amino acids are added to diets to increase productivity. Balancing of diets using amino acids also decreases excretion of nitrogen from the animals into the environment.

Enzymes: The use of enzymes in animal nutrition has an important role in current farming systems. Feed enzymes can increase the digestibility of nutrients, leading to greater efficiency in feed utilization. In addition, they can degrade unacceptable components in feed, which are otherwise harmful or of little or no value. Currently, feed enzymes available commercially by catalytic types are: 3-phytase, 6-phytase, subtilisin, galactosidase, glucanase, xylanase, -amylase and polygalacturonase, and most for the swine and poultry segment. The use of enzymes as feed additives is restricted in most countries by local regulatory authorities. The use of phytase

in pig and poultry feeds in intensive production systems in developing countries is significant. Phytase addition can reduce phosphorus excretion by up to 50%, contributing significantly to environmental protection. It also increases profitability (phosphorus resources are limited and expensive) by decreasing the amount of phosphorus added to the diet and increasing productivity by improving the availability of minerals, trace elements and nutrients for the animal. The animal feed enzyme sector grew at a rate of 4 percent per year between 2004 and 2009 and it is expected to grow annually by 6 percent. Exogenous enzymes such as xylanases, glucanases, proteases and amylases and their mixtures are also added to the diets of monogastric animals in commercial farms. The use of cellulases and xylanases has the added advantages of increasing digestibility, thereby reducing the amount of manure and possibly methane emissions from ruminants.

Single cell protein: From the 1970s to the 1990s extensive research was conducted on single cell proteins. Except for some algae, however, they are not being incorporated in livestock diets in either developing or developed countries. Algae such as azolla and lemna are used to a limited extent as feed for poultry and pigs by small-scale farmers.

Solid-state fermentation: The degradation of wheat and rice straws and other lignocellulosic materials using white rot fungi that degrade lignin was also extensively researched from the 1970s to the 1990s. In general, however, the nutrient availability from the treated material is decreased due to the consumption of carbohydrates present in the lignocellulosic materials by the fungi for their growth and metabolism. The nitrogen content of the treated material is higher, but a large proportion of this nitrogen is contributed by nucleotides, which do not increase productivity. Probably for these reasons, this technology has never got off the ground but solid-state fermentation for producing enzymes, especially phytase for animal feeding is being employed commercially.

Probiotics and prebiotics: Probiotics are live microorganisms which, when administered in adequate amounts, confer a health benefit on the host. They are used in animal nutrition in a number of developing countries, mostly in monogastrics. Prebiotics are non-viable food components that confer a health benefit on the host associated with modulation of the microbiota. Live microbes such as Aspergillus oryzae and Saccharomyces cerevisiae are being used increasingly in ruminant diets to improve rumen efficiency, especially in intensive production systems. A success story in the use of live microbes for ruminants is the introduction of a bacterium Synergistes jonesii into the rumen. It prevents mimosine toxicity and enables the safe use of Leucaena leucocephala as a protein-rich feed in many developing countries.

Silage additives: The use of bacteria such as Lactobacillus plantarum, L. buchneri, L. acidophilus, Streptococcus bovis, Pediococcus pentosaceus, P. acidilactici, and Enterococcus faecium and yeasts such as Saccharomyces cerevisiae alone or their mixtures, and the use of enzymes (cellulases, amylase etc.) alone or as a mix with microbial inoculants in silage production is restricted to few intensively managed

commercial dairy and beef production farms in developing countries.

Recombinant metabolic modifiers: The beneficial effects of recombinant somatotropin in most farm animals are well established. Recombinant bovine somatotropin (rBST) increases feed conversion efficiency and milk yield. The increase in milk yield has been reported to be about 10-15%, both in developed and developing countries. Administration of rBST to lactating Holstein cows also improved milk yield during heat stress without compromising fertility. However, before adopting this technology, an economic analysis of the production unit should be available. Regular administration of recombinant somatotropin could also become a constraint under some production conditions. The risks of increasing mastitis or other pathogenic infections (the elimination of xenobiotics is slower in animals receiving rBST) and the negative effects of rBST on fecundity and fertility when administered before breeding must also be taken into consideration before introducing this technology.

Molecular gut microbiology and rumen microbe genomics: Although at the research stage, these approaches have high potential for increasing livestock productivity by providing a better insight into the digestive physiology of livestock. The understanding about the role of strict anaerobic rumen microorganisms in the digestion of feed, the microbiological transformations that occur in the rumen, and the physiological importance of the products released from feed because of microbial digestion has increased. The use of 16S rRNA gene sequences to classify and identify rumen microbes based on DNA sequence and the development of PCR revolutionized the study of diversity and complexity of ruminal microbial communities without the need to culture them. So far, the direct benefit of these advances to developing countries has been by providing a means to track the establishment of a bacterium, Synergestis jonesii (which degrades mimosine, a toxic component) in the rumen by using a PCR based technique, enabling better utilization of Leucaena luecocephala leaves as livestock feed. The rumen microbiome modification research has been done at ICAR-NIANP to reduce the enteric methane emissions from the ruminants. Different products have been developed to modify the ruminal microflora and metabolism to reduce the enteric methane production namely Harit Dhara and tamarin Plus from ICAR-NIANP, RESMI from ICAR-CIRB and Methlow from IVRI, Avibattika from CSWRI. The approach also improves the body weight gain as well as milk production from 5-10 %.

Biotechnologies in animal health

Diagnostics and epidemiology: Advanced diagnostic tests that use biotechnology enable the agents causing disease to be identified and the impact of disease control programmes to be monitored more precisely than was previously possible. Molecular epidemiology characterizes pathogens (viruses, bacteria, parasites and fungi) by nucleotide sequencing, enabling their origins to be traced. This is particularly important for epidemic diseases, in which pinpointing the source of the infection can significantly improve disease control. Enzyme-linked immunosorbent assays have become the standard means

of diagnosing and monitoring many animal and fish diseases worldwide, and the PCR technique is especially useful in diagnosing livestock disease. PCR-based diagnostics are increasingly used for the early diagnosis of disease. Molecular epidemiology is one of the most powerful applications of gene-based technologies in animal health. PCR-based techniques are used in molecular epidemiology to compare sequence data on PCR products to determine the genetic relationship of the disease-causing agents, thereby facilitating the determination of their source, monitoring their spread, and providing new information about their biology and pathogenicity. The information obtained from such investigations helps develop appropriate strategies for the diagnosis and control of diseases and to monitor the impact of disease control programmes. Molecular genetic analysis studies of rinderpest viruses have contributed substantially to the Global Rinderpest Eradication Programme (GREP). Similar studies on virus serotypes associated with FMD were useful for vaccination and control programmes.

Improving health through developing vaccines: Two main approaches are being used to develop vaccines using recombinant DNA technology. The first involves deleting genes that determine the virulence of the pathogen, thus producing attenuated organisms (non-pathogens) that can be used as live vaccines. Currently, this strategy is more effective against viral and bacterial diseases than against parasites. Attenuated live vaccines have been developed against many animal pathogens. The second approach is to identify protein subunits of pathogens that can stimulate immunity. Vaccination is one of the most effective and sustainable methods of controlling disease. A recent approach has been to use vaccines based on DNA. The use of DNA in vaccines is based on the discovery that injecting genes in the form of plasmid DNA can stimulate an immune response to the respective gene products. This immune response is a result of the genes being taken up and expressed by cells in the animal after injection. The use of DNA vaccines in farm animals, including cattle, pigs and poultry need specific attention before this technology can be used routinely. These areas include the delivery, safety and compatibility of plasmids in multivalent vaccines and the potential for using immune stimulants as part of a DNA vaccine. In general, vaccines offer considerable benefits at a comparatively low cost, which is a primary consideration for developing countries. Molecular techniques can be used to produce a variety of different constructs of pathogenic agents and offer several advantages over more conventional vaccines such as: the deletion of the gene(s) responsible for causing disease and thus greater safety; increased stability; the possibility of developing vaccines against protozoan and helminth parasites; and differentiating between infected and vaccinated animals through detecting antibodies either against the peculiar proteins elicited by the vaccine or failing to detect antibodies against the deleted gene/protein. In addition to validated, robust, specific and sensitive diagnostic tools and safe and effective vaccines, control and eradication of animal diseases requires a complete package of good veterinary infrastructure, reporting

systems, laboratories with skilled staff, epidemiological units able to execute surveys, and a carefully designed plan with clear objectives. Regional and intergovernmental cooperation is also vital since many of animal diseases are transboundary. List of different vaccines produced at IVRI using different biotechnological tools is given as Annexure-I.

Sterile insect technique: The SIT depends on the integration of biological and engineering techniques to produce on an industrial scale and release, usually by air, adequate numbers of reproductively sterilized insects of the target pest in areas where it severely threatens the environment, agriculture or livestock production. Virgin female individuals in the target insect pest population that are mated and inseminated by released sterile male insects do not produce any offspring. Repeated inundative releases of mass-produced sterile insects can be integrated with suppression, eradication, containment or prevention strategies against key insect pests. The African Union's Pan-African Tsetse and Trypanosomiasis Eradication Campaign (AU-PATTEC) is coordinating various national programmes that aim to integrate the SIT for creating selected trypanosomosis- and Tsetse-free zones in Ethiopia, Kenya, Senegal, Uganda, Tanzania and in a transboundary area in Mozambique, South Africa and Swaziland. At present, there are many uncertainties surrounding the production and use of transgenic insects due to instability of the insertion and expression of the transgene. In addition, it requires addressing public concerns and putting in place a regulatory mechanism to properly conduct a risk assessment.

Animal biotechnological options

Application of biotechnologies should be supported within the framework of a national livestock development programme: Our country may ensure that animal biotechnologies are deployed within the framework of national development programmes for the benefit of producers and consumers and not as stand-alone programmes. The models of biotechnology interventions in developing countries differ distinctly from those in developed countries. The biotechnologies that are simple and cost-effective are more likely to be successful in developing countries. To ensure the successful application of a biotechnology in the complex and diverse animal agriculture scenarios present in developing countries, not only does the mitigation of technical challenges need to be addressed but also, and probably more importantly, issues like management, logistics, technology transfer, human capacity, regulation and intellectual property. Policymakers should be aware that there would be practical, financial and legal obstacles that will preclude the full-scale adoption of many livestock biotechnologies. Therefore, strong scientific drive, vision and entrepreneurial skills are needed for contributing to progress in animal biotechnologies in India.

Access to biotechnological products by end users should be ensured: An appropriate model for scaling up and packaging the technology should be integrated into the development and application of

biotechnologies and biotechnological products, particularly for vaccines, diagnostics, probiotics, prebiotics and enzymes so that the products are not cost-prohibitive. It has to be borne in mind that the target end users of these biotechnologies are normally resource-poor farmers with limited purchasing power. Without this scaled-up business approach/model, even good science and quality biotechnological products might not deliver desired impacts at the field level. In the business model, it is also imperative to consider the intellectual property issues, which impinge on several aspects of biotechnology.

Initiatives of Department of Biotechnology, GoI

Mandate and Thrust Areas in Animal Biotechnology: The mandate of this Division is the sustainable growth of livestock for nutritional security and economic prosperity as well as enhances production and productivity through biotechnological interventions.

- To establish collaborative research for development of new generation vaccines and diagnostics along with translation of existing candidate vaccines and diagnostics for field use around major animal disease of national importance to make product affordable to small and marginal farmers.
- To provide R&D support for generation of new knowledge in the priority areas livestock production and to develop skill pool to meet R&D requirements of the sector.
- To enhance production and productivity of livestock sector through biotechnological interventions in nutrition, breeding, genetics and by-products etc.
- To achieve excellence in innovation, technology generation for enhancing animal production in the country.
- To implement 'ONE HEALTH' research platform to address issues related to mitigation of existing and emerging zoonotic diseases
- To conduct basic and applied research in nutrition using physiological and nutritional approach.

New Initiatives

- Network Programme for 'Bovine Sexed Semen Sorting Technology (BSSST)'
- PAN India network program on Canine Health Research - Phase II

Major Programmes

One Health Initiative: Department has established a "One Health Center" at National Institute of Animal Biotechnology (NIAB), Hyderabad for inter-sectoral collaboration among veterinary, medical, agricultural, environmental, forestry, meteorological and other areas to detect, prevent and control zoonoses and transboundary animal diseases. Further, a mega-project "Establishment of a Consortium for One Health to address Zoonotic and Transboundary Diseases in India, including the Northeast Region" consisting of 28 organizations led by DBT-National Institute of Animal Biotechnology, Hyderabad has been supported. The One health consortium consists of AIIMS, Delhi, AIIMS Jodhpur, IVRI, Bareilly, GADVASU, Ludhiana,

TANUVAS, Chennai, MAFSU, Nagpur, Assam agricultural and veterinary university and many more ICAR, ICMR centres and wildlife agencies. This programme envisages carrying out surveillance of important bacterial, viral and parasitic infections of zoonotic as well as transboundary pathogens in India, including the North-eastern part of the country. The consortium designed sampling strategy, and finalized the assays, kits and standard operating procedures (SOP). Meta-analysis of existing literature was carried out to design the sampling frame for various species of animals, and hospital-based syndromic approach was used for humans. About 12,000 animal samples, around 3000 food-related samples, 650 wildlife samples and more than 5000 human samples have been collected and tested.

Translational Research Platform for Veterinary Biologicals (TRPVB): TRPVB is a partnership initiative between the Department of Biotechnology (DBT) and TANUVAS-Chennai, to facilitate a collaborative and coordinated approach for the translation of technologies in veterinary vaccines and diagnostics. Several universities and research institutions are performing research on the development of animal vaccines and diagnostics, but very few products have been commercialized in this sector. TRPVB was created with the vision to foster 'Productization' in the field of Veterinary Biologicals by converging the presently distant academic research, industry and pathways of regulatory compliance. TRPVB works towards to achieve the mission of translating of veterinary vaccines, diagnostics and other Biologicals for field application and harness their benefit to improve animal health and productivity thereby augmenting the economic status of farmers. Over the past more than 12 years, TRPVB has become a centre of reference to strengthen national, regional and international linkage and collaboration for animal vaccine and diagnostics development, exchange of materials, technology assessment, regulation, and knowledge sharing to support training, consultation and commercialization of technologies.

Network Programme on Anthrax Diagnosis and Control in India: A network programme on 'Anthrax Diagnosis and Control in India' has been supported by the department to provide a multi-disciplinary research consortium with involvement of 10 partnering Institutes/Universities to strengthen the competences for surveillance, outbreak investigation, laboratory capacity, vaccination, specific predictors of outbreak risk and risk mapping. A 'latex agglutination test for detection of B. anthracis spores in animal feed supplements and soil samples' and a 'portable UV aluminum cabinet for inactivation of B. anthracis spores in the soil' have been developed in this project and are under validation stage. Whole genome sequencing and comparative analysis of 17 isolates from several animals (e.g., sheep, cattle, pigs, deer, goat, and contaminated soil sample) infected with B. anthracis has also be completed. Further, cryopreservation and molecular characterization of 23 isolates of B. anthracis obtained from different infected sites in India has also been done. Transgenic sorghum and rice plants have been successfully generated for the gene encoding for the domain IV

of protective antigen and cholera toxin B subunit.

Bovine Sexed Semen Sorting Technology: Department conducted a Brainstorming meeting on 'Bovine sexed semen sorting technology' and reviewed the current status of research leads developed in this area and identified new research area for the development of indigenous technology. Further, based on this Brain storming meeting, Department constituted an Interdisciplinary Group of Expert and formulated a Call for Proposal on "Bovine Sexed Semen Sorting Technology (BSSST)" and three consortia projects have been supported using different approaches viz Aptamer and protein targeted approaches for sex specific spermatozoa enrichment in Bovines; Integrated Magneto-Acousto-Dielectrophoresis based microfluidics for the sorting of Bovine spermatozoa; and redesigning of FACS instrument for sorting Bovine Spermatozoa.

Canine Health Research: Dogs are the true companions of human since antiquity however, funding for canine health Research has been given a least priority. Even, Hon'ble Prime Minister of India has emphasized a need to research on indigenous dog breeds of India. Department supported two major PAN India Network programmes at Tamil Nadu Veterinary and Animal Sciences University (TANUVAS) Chennai, Tamil Nadu and Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana, Punjab. The major research purpose of these programs was on canine haemoprotozoan parasites, oncology, canine blood typing, canine enteric virus, canine contraception, canine ocular disorders and canine leptospirosis. In phase-I, outstanding research leads were generated, thereafter, keeping in view the outcomes of phase-I, DBT supported its Phase-II program for validation and commercialization of technologies/ Products/Protocols/Feed developed during phase-I.

Key Achievements and Success Stories

Nanostructured paper-kit comprising magnetic nanoparticle for rapid detection of subclinical and clinical mastitis: An early detection of mastitis at subclinical stage holds high prognostic value as starting the medication at an early stage leads to rapid cure of the condition. NIAB-Hyderabad has developed and validated a field level, affordable, farmer friendly quantitative method to diagnose intra-mammary infection as well as subclinical mastitis (Limit of visual detection: 25,000 cells/ml of milk). Further, a technology has also been developed to perform on-field anti-microbial sensitivity testing within 2 hours' time under field condition. Both the assays don't require any trained personnel for performing as well as interpreting the assay results and it can be performed at the doorstep and under field conditions. These technologies have been transferred to ACS Neoteric Technologies LLP Hyderabad for commercialization. Other diagnostic kits developed at IVRI are given in Annexure-I.

Subviral Particle Based Infectious Bursal Disease Vaccine: A technology named "Subviral Particle Based Infectious Bursal Disease Vaccine" intended for use against IBD also known as Gumboro disease of poultry, which was developed with the funding support of

Department of Biotechnology has been transferred to M/s. Hester Biosciences, Ahmedabad on 28.02.2024 by IVRI-Bareilly and Agrinnovate (AgIn), New Delhi. The SVP based vaccine completely protects the broiler birds in presence of maternally derived antibodies (MDA) and can safely be administered to day-old chicks. The vaccine does not cause immunosuppression as has been demonstrated by an intact histological architecture of the Bursa of Fabricius in immunized birds.

Genomics for conservation of indigenous cattle breeds and for enhancing milk yield: The Department supported a program for the development of high density single-nucleotide polymorphism (SNP) chip for identification of pure indigenous cattle breed as well as elite animal at National Institute of Animal Biotechnology (NIAB), Hyderabad. Through this project, genotyping and sequencing of the 43 indigenous registered cattle breeds including five major cattle breeds - Gir, Tharparkar, Kankrej, Red Sindhi and Sahiwal were performed. The Chip named as IndiGau which is the largest cattle chip of the world. It has 11,496 markers (SNPs). This is the first chip developed for Bos indicus (Indian breeds). Further, India's first SNP based chip for the conservation of pure varieties of indigenous cattle breeds has been released by Dr. Jitendra Singh, Hon'ble Minister of State (IC), M/o S& T on 13th August 2021.

Early pregnancy diagnosis in cattle and buffalo: The Preg-D kit, the prototype of a urine based novel technique for pregnancy diagnosis in dairy animals has been developed with support of DBT at the ICAR-Central Institute for Research on Buffaloes, Hisar. This innovative kit employs a thermophilic biochemical reaction to detect metabolites, resulting in the formation of a coloured precipitated compound in positive cases. The kit will preliminarily diagnose the pregnancy as early as day 18-25 in bovines. It does not require any instrumentation and results can be interpreted by naked eye as well as the kit is non-invasive, cost-effectiveness, user-friendly and animal friendly.

Nano-Newcastle disease virus vaccine: Newcastle disease is a highly contagious disease of birds caused by a para-myxo virus. TRPVB at TANUVAS-Chennai has developed a Nano based Newcastle disease virus vaccine. This is the first nanotechnology-based vaccine of our country that has been licensed for commercial production and use in chickens. This technology has showcased the benefits of nanotechnology applications in vaccine delivery systems. This reiterates that successful 'productization' is possible through active academia-industry-funding agency linkage and is a testimony to Aatmanirbhar Bharat. The advantages of this vaccine are two-fold. The vaccine is effective at 100-times lower dose than conventional (non-nano) vaccine. This implies that 100 times more doses can be manufactured with the same volume of virus-infective fluids than conventional vaccines. Further this nano vaccine is found to be more effective in the face of maternal antibodies while the conventional live vaccines would get neutralized by them. The technology of nano Newcastle disease virus vaccine production has been transferred to M/s. Hester Biosciences Limited, Ahmedabad. The recipient company, after complying

with all the regulatory processes, has received manufacturing license for the Newcastle disease vaccine Live Nano for both domestic use and export purpose.

Brucella delta S19 vaccine: Department has successfully completed a network programme on bovine brucellosis in which an improved brucella vaccine viz. modified delta S 19 vaccine has been developed. Safety and potency of delta S 19 vaccine has been done in mice model and evaluated successfully in buffalo. Delta S19 vaccine is safer in comparison of existing vaccine without any side effect. The technology of Brucella abortus S19Δper vaccine has been transferred to M/S Hester Biosciences ltd on 22nd September 2020 for commercialization.

Embryo transfer technology: The department supported a mission mode programme to enhance the productivity of livestock and emphasis was given on standardization of various techniques of Embryo transfer technology (ETT). The technology was successfully standardized in cattle, buffalo, goat, equine, camel and yak. The department established three main ETT centre and 14 regional ET labs in different parts of the country. Various techniques viz. super ovulation, in vitro culture of embryos, embryos transfer etc. were standardized. ETT demonstration activities were undertaken at the farmers level and a number of cattle and buffalo calves were produced. With the help of ETT an intensive selection among male and female livestock can be carried out in elite herd at an early age using the family information and thus reduce the generation interval and bring about desired change in short span of time.

Open nucleus breeding system: The department initiated Open nucleus breeding system (ONBS) for enhancing the productivity of Sahiwal and crossbred Sahiwal cattle at National Dairy Development Board (NDDB), Anand. The nucleus was established from the best animals obtained by screening the base population. During the project duration, 268 male calves and 259 female calves were produced through embryo transfer. This programme was adopted by NDDB, Anand for continuous production of male Sahiwal and crossbred males for National Artificial Insemination programme.

Genetic Improvement: Genetic improvement of local sheep breed of Kashmir and Maharasthra using Fec B mutation, and their genetic characterization were carried out successfully. Approximate 45% more lambs were produced by the heterozygous ewes having Fec B mutation whereas homozygous ewes gave birth to 65.5% more lambs than non carrier ewes. The study confirmed two distinct groups among FecB carrier crossbred ewes with low and high average litter size. Department of Animal Husbandry, Govt. of India has adopted this programme and a national programme on genetic improvement of sheep breeds was launched.

Genome Editing technologies for improving the productivity, climate resilience and disease tolerance: The CRISPR/CAS system, and previously TALEN and ZFN, are relatively recent genome editing tools that will contribute to the global livestock transformation. Applications of genome editing include improving productive and fitness traits in large animals, enhancing animals to achieve adaptation and resilience to ensure animal welfare, generating resistance to infectious and transmissible

diseases, as well as controlling pests and disease vectors. The main use to date is CRISPR's ability to edit the genome acting as molecular scissors with the ability to edit any given sequence including a single nucleotide.

Conclusion

Biotechnology is a support for various fields of agricultural production and processing and offers a range of tools to advance our understanding, management and use crop and livestock resources for different social and economic benefits of man. Till now, biotechnology in animal production has been applied only in a few areas such as conservation, animal improvement, healthcare (diagnosis and control of diseases) and augmentation of feed resources. Adopting biotechnology has benefitted by in animal improvement and economic returns to the livestock entrepreneurs and small producers. Concisely, investing in animal production and biotechnologies is necessary because it can bring social sustainability, economic prosperity, food security and safety, rural wealth creation and health improvements especially to poor populations in the developing countries. Therefore, the following points are recommended to strengthen the animal biotechnology capacity in India and realize its benefits.

1. Effective biotechnology policy directives and biosafety system as well as regulatory and monitoring mechanisms should be followed, in particular, for the introduction, research and release of genetically modified organisms.
2. Applications such as microbial products development, vaccine production and diagnostics, alternatives to antibiotics, should be expanded.
3. The wise utilization of the animal biodiversity by in vitro conservation, molecular characterization and introduction of marker assisted breeding and isolation of potentially useful genes should be promoted for production as well as identification of climate resistant indigenous breeds for different eco regions of India
4. To reduce the animal biotech product and solutions development timeline for livestock technologies, vaccines, diagnostics and therapeutics, in silico biology approaches through Bioinformatics, Molecular modelling, AI & ML should be encouraged.
5. Establishing and sustaining institutional linkage within the country as well as strengthening collaboration among Developing and Developed countries should be improved.
6. Policies and incentive mechanisms should be developed to encourage private sector investment and their participation in Animal biotechnology research & development.
7. Universities offering biotechnology courses should upgrade their laboratory in terms of manpower and facilities to acquaint the students with practical skills and produce competent manpower, Opportunities in entrepreneurship development in animal

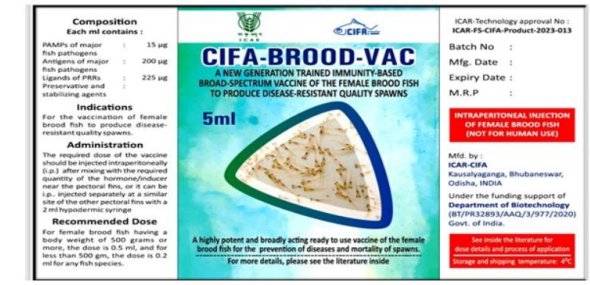
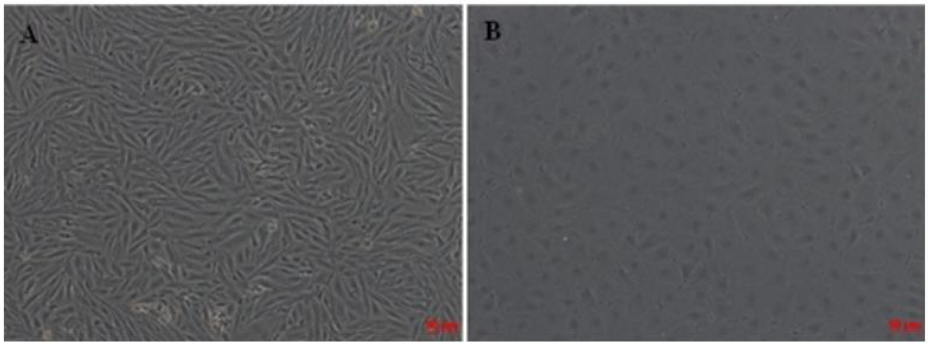


Figure1: CIFA-Brood-Vac



biotechnology sector.

8. Finally, an active interaction between institutions, scientists and other stakeholders including the farmers, veterinarians and decision makers should be held in a periodic manner.

2.4 Aquaculture and Marine Biotechnology

The Aquaculture and Marine Biotechnology program of GoI has been implemented with the goal of enhancing both aquaculture production and productivity, while also harnessing marine resources for valuable products and processes. This program plays a vital role in the agricultural economy by ensuring food production for nutritional security. The Department has undertaken various initiatives to benefit the aquatic and marine sectors through this program. These initiatives include the development of novel cell lines, improvement of aqua feed, creation of advanced diagnostics and therapeutics, research on fish genomics and transcriptomics, management of fish and shellfish diseases, exploration of marine ornamental resources, and engagement in bio-prospecting activities. The major goals of this programme are:

- To enhance fish production through sustainable utilization & development of natural resources
- To facilitate the conservation of the natural aquatic and marine resources for improving the ecosystem and the

deter the climate change

- To develop the aquatic and marine available resources as nutraceuticals
- To develop the technology for aquatic and marine animals' disease diagnosis and their treatment
- To develop the feed for sustaining the fisheries sector
- To augment the development of constituents of aquatic or marine reserves /resources for mankind healthcare and waste management
- To conserve the aquatic/marine ecosystem

Key Achievements and Success Stories

- Polychaete worms are rich sources of nutrients such as PUFA, enzymes, and hormones which help in oocyte development and maturation of shrimps. Research supported by DBT at ICAR-CIBA Chennai has developed a simple small scale culture method for Mud worm Polychaete Marphysa madrasi and marine sand worm Perinerisnuntia spp. Forty adults of M. madrasi, when reared in 100L tanks, produced approx. 2016 juveniles in four months, with 90%

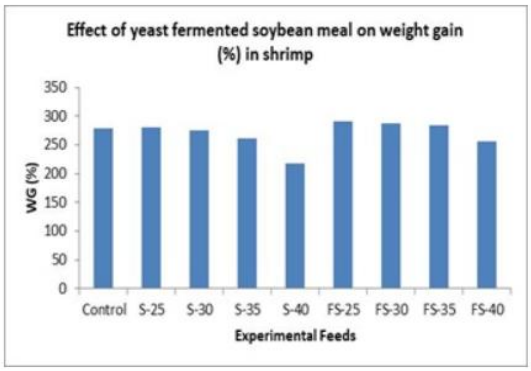


Figure 3(A). Effect of yeast soyabean meal on weight gain (%) in shrimp

Figure 3(B). Pilot Scale Solid State Fermentor Funded by DBT

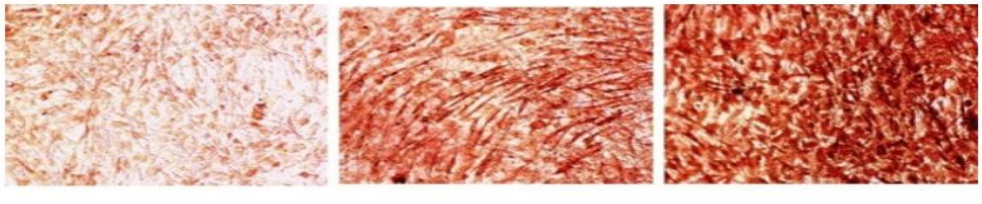


Figure 4(A). Effect of GAGs on Collagen Production

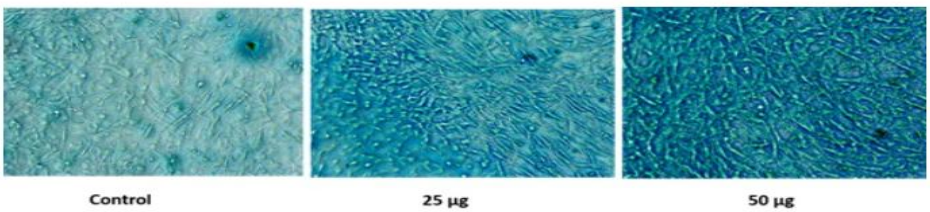


Figure 4(B). Effect of GAGs on Extracellular Matrix Production

survival. Around 500 juveniles were mass-reared in a 1000 L FRP tank by feeding with diatom, Chaetoceros calciferons (106 CFU/ml) with a mixture of CIBA shrimp larvae feed which produced 400 adults with 80 % survival in 4 months (19± 0.3cm) with SGR under mass culture was 0.33. The net weight gain was 0.33 g for juveniles with biomass.

- Perna viridis is considered an important species for aquaculture in India and is widely cultured along the southwestern coast, especially Kerala and Karnataka. The De Novo whole genome and transcriptome sequencing of the Asian green mussel, Perna viridis using advanced genomic methods was carried out at ICAR-CMFRI, Kochi. The final assembly resulted in a genome of 723.49 Mb in size with a scaffold N50 of 49.74 Mb. The BUSCO completeness of the assembly has been evaluated as 96.8%. Further, the expansion of inhibitors of apoptosis gene families and caspase gene families was observed indicating their tolerance to environmental challenges.
- Disease of spawn and fry and their mortality are one of the major problems in the expansion of aquaculture. To address this problem, a project being implemented at ICAR-CIFA, Bhubaneswar with the support of DBT has led to the development of a vaccine named “CIFA-Brood-Vac” which can prevent diseases and mortality of spawns. This vaccine has been tested extensively in various hatcheries of Odisha and West Bengal confirming its efficacy in producing disease resistance spawns (Figure 1).

An effort was made to develop whole virus vaccines against cyprinid herpesvirus-2 (CyHV-2) and tilapia lake virus (TiLV) under the DBT-supported project being implemented at CAHC, Melvisharam/ICAR-CIFA, Bhubaneswar and KUFOS, Cochin. These viruses are responsible for mortality of goldfish and tilapia respectively. The researchers have produced whole virus vaccine against CyHV-2 and TiLV using susceptible fish cell lines. The vaccine trails are being carried out at ICAR-CIFA and KUFOS. TiLV whole virus vaccine is shown to be efficient in imparting tilapia protection against the virus (Figure 2).

Fish meal is the important ingredient in shrimp feeds. Due to its high cost and sustainability issues, replacement of fish meal is an important area of research in aquaculture nutrition. Scientists working in this area at ICAR-Central Institute of Brackish water Aquaculture, Chennai have shown in their studies that yeast fermentation of soybean meal significantly improves inclusion level in shrimp diet by increasing the nutrient digestibility and growth. The growth trial results indicated that soybean meal can be included up to 35% in the grow-out feed of P. vannamei and fermentation improved the growth by approx. 8.5%. (Figure 3)

Fish waste has so far not been exploited for large-scale isolation of glycosaminoglycans (GAGs). Scientists at CSIR-CFTRI, Mysuru have developed a protocol for its isolation, which is novel, sustainable, economical, and eco-friendly green method. The isolated GAGs were characterized for structure and was found to be a mixture of chondroitin/dermatan sulfate (CS/DS) and heparansulfate in the ratio 80:20. The isolated GAGs were able to promote osteogenesis in MC3T3 cell and promote wound healing in HCAT cells. Studies on the mechanism of exogenous GAG-mediated osteogenesis is underway. (Figure 4)

In another study focused on live feed for aquaculture undertaken by researchers at AMET University, Chennai has identified a new approach using monoalgal diet and adopting selective breeding method for high density culture of A. royiand P. serricaudatus copepod species. Improved growth and survival of Asian seabass, L. calcarifer larvae and critical first feeding stage of silver pompano, T. blochii larvae was achieved with A. royinauplii compared to the traditional rotifers live feed. Indigenous copepod

live feed protocol has been developed for successful marine finfish larval seed production.

Monitoring variables such as dissolved oxygen, pH, tds and pond temperature is a key aspect of high-quality fish farming. An Intelligence forecasting approach is required to address the complexity of farmer's crop monitoring issues, scientists at Vel Tech Rangarajan R&D Institute of Science and Technology, Chennai have developed a hybrid intelligence mechanism for forecasting efficiently and handling a large amount of streaming data through Auto regressive long short-term memory integrated moving averages (ARLSTMIMA). The intelligent algorithm is embedded into Tiny ML an IoT device developed for getting real-time data. As a result of this procedure, the pond's water quality and environmental conditions can be continuously checked to guarantee a healthy prawn crop.

DBT funded National Repository of Fish cell lines established at C Abdul Hakeem College for conducting research on application of cell lines in virological and biomedical research have reported development of novel cell lines from Asian seabass and Osteobramabelangiri. They have also isolated reported new viral pathogens (CyHV-3 and tilapia parvovirus) using cell lines for vaccine production. In addition to this, the center has so far imparted fish cell culture training to 29 trainees and helped 11 PhD scholars for short term research using fish cell line.

2.5 Bioinformatics

Agricultural Bioinformatics in association with biotechnology has potential application to address longstanding issues in agriculture. Increased use of applications of bioinformatics in agriculture was due to the latest developments in functional genomics, Next-Generation Sequencing (NGS) tools, Whole-Genome Sequencing (WGS), Data mining techniques, genotyping assays, Genome-Wide Association Studies (GWAS). Sequencing-based trait mappings require high-performance computing (HPC) facilities and expertise. The exponential growth of data in commensuration with the demand for visualization, integration, analysis, prediction, and management helped the breeders, biotechnologists, and agriculture scientists to address the pertinent issues. However, many agricultural researchers are still unfamiliar with the available methods, databases and bioinformatics tools, which may lead to misinterpretations or lacks informational opportunities. The potential use of bioinformatics is the availability of various tools (for storage, retrieval, analysis, and annotation of results) and large genomic resources to vast pool of agricultural scientists. This is all possible only when data are analysed using appropriate bioinformatics tools. However, the major issues concern is lack of infrastructure facilities like HPC, computational tools, lack of opportunities for training for skill up-gradation, lack of largescale research initiatives at the national level, etc. Capacity building of National Agricultural Research and Education System (NARES), skilling or reskilling of scientists and students of agricultural and allied sciences on different tools of bioinformatics at the national and international level is another key issue to be addressed. The NAARM and IASRI are to play an important role in the capacity building of the scientists

and students of NARES, which can be extended to industry and agri startups as well.

The creation of a separate Bioinformatics department/centre in colleges under State Agricultural Universities (SAU)/ Central Agricultural University (CAU)/ institutes would strengthen the research and development. The proactive step is to fund all the Bioinformatics departments/centres for at least 5 years by ICAR to establish/strengthen requisite infrastructure for its sustainability. The databases, software, and bioinformatics tools generated/developed by ICAR institutes/SAUs are to be integrated into national repositories created centrally at an institute identified for the purpose. Protection of databases and Intellectual Property Rights (IPR) are utmost critical issues. The implementation of the much-needed strategies require support from the NARES to reap the benefits of the newly emerging science in agricultural education. The use of bioinformatics in agricultural research and education can happen through certain proactive steps of NARES supported by exclusive budgetary allocation, creation of infrastructure, and curriculum changes.

"Bioinformatics is the interdisciplinary field of biology and computer science concerned with the collection, storage, analysis and dissemination of biological data, most commonly DNA and amino acid sequences. Bioinformatics uses computer programs for a variety of applications, including predicting biological data sequence and determining the function of genes and proteins, the three-dimensional structure of proteins, phylogeny, and drug development. To date, bioinformatics has had the greatest impact in areas as diverse as human health, the environment, energy, biotechnology and agriculture."

By 2050, the global population is expected to increase by 9.2 billion and simultaneously the demand for food by 70%. To meet this huge demand of the burgeoning population, multi-pronged approaches are required, apart from improving the productivity of crop, animal, and fish using omics approaches. The modern genetic improvement programs integrate omics information for faster and more precise decisions during genetic purity genes introgression and plant/animal selection. The information to be deployed in these programs comes from basic omics studies involving huge data analysis procedures. For example, qualitative improvement in crops to ensure adequate availability of nutritionally enriched agri-produce to curtail the global rise in obesity, diabetes and address the issues of malnutrition, anaemia, and zinc deficiency in the developing world.

Developments in agricultural biotechnology have accelerated during the last decade as a result of genome sequencing and RNA of a large number of agriculturally important species, in addition to ongoing efforts of solving crystal structures of proteins and related study on metabolites associated with various traits. The high-throughput large-scale data is generated through different omics (genomics, epigenomics, transcriptomics, proteomics, metabolomics, and interactomics) platforms for understanding the plant attributes, important to increasing productivity, stress resistance and quality. This, combined with developments in information technology, has led to the emergence of bioinformatics, a

super specialty that the biotechnology has become increasingly dependent on resource intensive approaches. It is increasingly on the cutting edge of applied science and is essential to modern biological research, a 21st century science. The Genomic Revolution has highlighted the vital role of bioinformatics in understanding the basis of life processes and their possible manipulation for the benefit of mankind.

Analysing the big data generated in different laboratories, to get acute input for genome-based selection leads to faster genetic gain. Pragmatically, this will facilitate improved yields with quality comparable to domestic and global markets. The success of a genome-based approaches to improving agricultural productivity is critically dependent on relating the phenotype with the genomic data in the form of association studies along with a faster and more accurate predictions of breeding values. Through Genome-Wide Association Study (GWAS), the genetic factors for target attributes can be identified using thousands of SNP markers in plants and animals and through genetic mapping in family-based populations in plants. Such a computational approach leading to the identification of key genes along with their desirable/undesirable alleles and haplotypes has paved the way for 'Genome Editing' having huge potential of developing customized cultivars as per requirement. CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) and CRISPR associated (Cas) proteins have been utilized recently for Genome editing in plants and animals (Biswal et al. 2019; Aglawe et al. 2018). The quick delivery of the new breeds with high precision and specificity makes the gene editing tool the choice of next-generation breeding programs. Bioinformatics plays a critical role in designing the appropriate guide RNAs, engineering better nucleases, and predicting the possible off-targets. Further discovery of superior haplotypes for target attributes has added another dimension to the existing efforts on the identification of controlling genetic factors.

Computational biology has to play a pivotal role in the application of genomics in agriculture right from Whole-genome sequencing to the development of Genomic selection tools. This will ensure increased productivity and effective pest and disease management of crops, animals and fish. The critical challenge of the molecular biology community is understanding the vast amount of data generated by genomic and RNA sequencing projects. Today, biologists are collaborating with scientists from a wide range of disciplines to understand how complex biological systems work. The

Biotechnology Information System Network (BTISNet)

The BPI–2004 (Bioinformatics Policy of India) has envisaged providing a framework for national strategies to be adopted in the coming years to promote and encourage the development of bioinformatics in India. Bioinformatics, through the joint efforts of the Department of Biotechnology (DBT) over the past 15 years, has made significant progress, particularly in infrastructure development, orienting the scientific staff to the use of computational approaches, and providing training to practising scientists. However, emphasis should be placed on the program's goal-oriented approach, the consolidation of resources and the creation of a workforce to meet growing national and international markets. At the beginning of the last decade, India tried to build an infrastructure that could use biotechnology through applications of bioinformatics. The government has made important strides in building a network of National Grid of Bioinformatics centres, such as the BTISNet, which paved the way for the establishment of a vast network of 169 centres pan India.

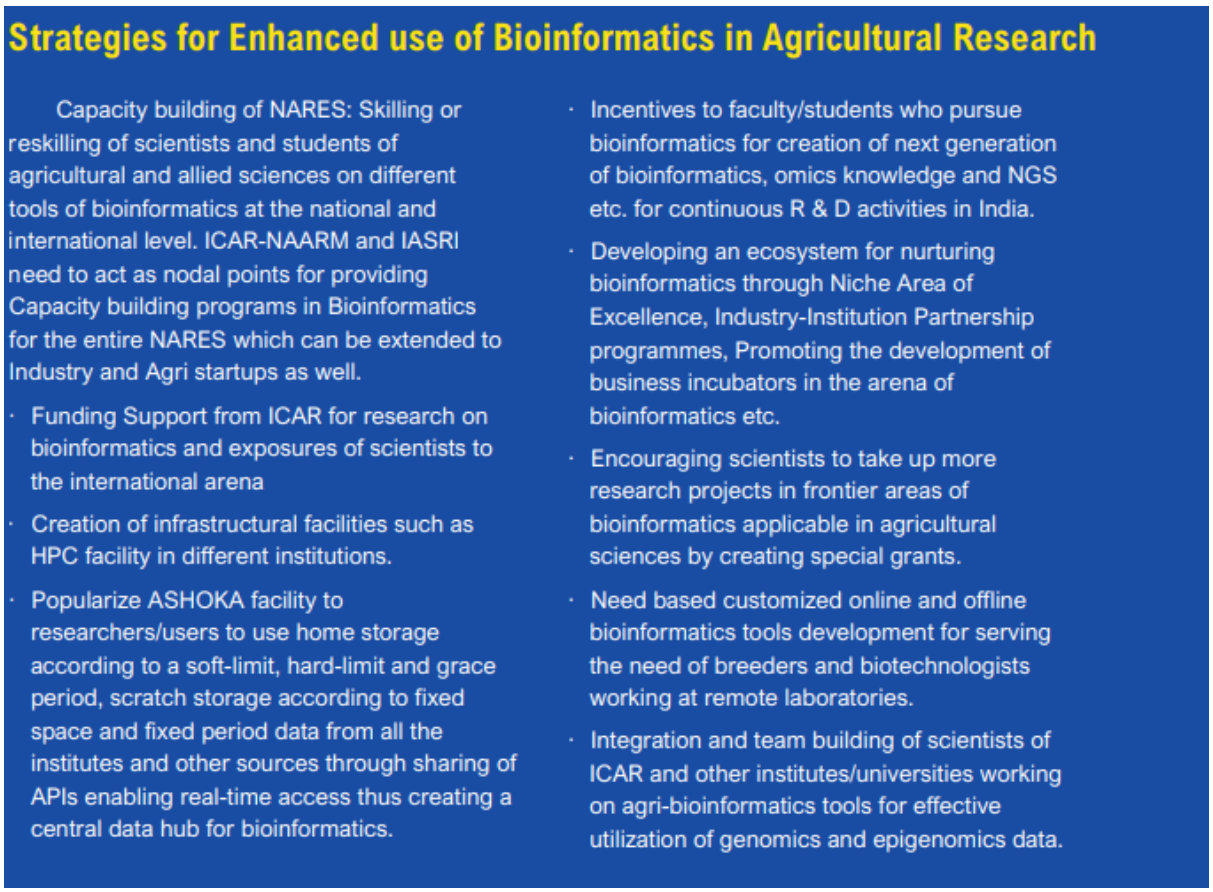
The Bioinformatics Policy of India-2004 marked the beginning of extensive coverage of national bioinformatics. It aims to develop excellent human resources through a schooling programme for scientists, research fellows, scholars and pursuing their careers in bioinformatics. These specialized assets may be promoted for research inside the discipline of agricultural bioinformatics (BPI, 2004).

The development of agricultural bioinformatics has caused a scientific revolution by developing new innovations in agricultural bioinformatics, and this development requires efforts to gain public trust in order to enrich the know-how of work. In this regard, the national wide biotechnology development strategy from 2015 to 2020 is to establish agriculture biotech partnerships with State Agricultural Universities (SAU) to research on transgenic plants in public institutions.

sequencing of the genomes of multiple organisms has led to many interesting discoveries about the facts regarding the precise genetic regulation of economically relevant traits of crops and animals. Today's the world unequivocally realizes the need for this discipline to save precious resources and time.

Over the past few decades, structural and functional genomics, data mining techniques, genome-wide association studies, and availability of high-performance computing facilities, and various bioinformatics tools/ databases are important to breeders, biotechnologists, and other discipline scientists. Realising the importance, the Indian Council of Agricultural Research (ICAR), identified bioinformatics as a high priority area th during the 12 plan period to ensure that this field achieves the required level of attention in the national arena. This can be achieved through Agricultural Bioinformatics in association with biotechnology has the potential to address longstanding issues in agriculture. Increasing applications of bioinformatics and computational biology tools for understanding genetic and epigenetic mechanisms involved in

the control of economically important traits of field and horticulture crops, forest trees, and livestock species necessitated the need for a specialized policy framework to optimize the benefits of the specialized field in addressing the pertinent issues of the agricultural sector in the country. It is an urgent need for creating a pool of bioinformaticians at different levels in India to tap the benefits of this stream in Indian agriculture. It is equally important to mention that this is a fast-progressing research field and hence, continuous up-gradation of skills should be an integral part of national strategy.



2.6 Forestry / Biodiversity

What is biodiversity?

More than 10 million different species of animals, plants, fungi and micro-organisms inhabit the Earth. They and the habitats in which they live represent the world's biological diversity, or biodiversity as it is often called. Humans use at least 40,000 species of plants and animals on a daily basis for food, shelter, clothing and medicinal needs. Much of the global concern with deforestation

focuses on the alarming loss of biodiversity. There is also considerable concern with the poverty of many forests dependent communities. Many poor communities around the world rely on local biodiversity for a range of essential services. These include materials for housing and clothing, food from a range of wildlife species and traditional medicines derived from local plants and animals. The populations of developed nations also depend on biodiversity for their survival and quality of life. Close to 40 percent of the pharmaceuticals used in the United States are either based on, or synthesized from, natural compounds found in plants, animals or microorganisms. The greatest value of biodiversity might still be unknown. Only a fraction of known species has been examined for potential medicinal, agricultural or industrial value. Nor do we fully understand how biodiversity contributes to the well-being of the larger global environment. And we are only just beginning to learn how biodiversity helps communities around the world satisfy their economic, dietary, health and cultural needs. One of the most certain thing is, the more we learn about biodiversity the more we realize how much the world depends on it. Yet whole species of plants, animals, fungi, and microscopic organisms are being lost at alarming rates.

Forest biodiversity: Forests are the most diverse ecosystems on land, because they hold the vast majority of the world's terrestrial species. Some rain forests are among the oldest ecosystems on Earth. Timber, pulpwood, firewood, fodder, meat, cash crops, fish and medicinal plants from the forest provide livelihoods for hundreds of millions of people worldwide. But only a fraction of known species has been examined for potential medicinal, agricultural or industrial value. Forest biodiversity is threatened by rapid deforestation, forest fragmentation and degradation, hunting and the arrival of invasive species from other habitats. We are losing 12 million hectares of forest a year, much of it tropical rainforest with its unique and rich biodiversity.

How can we protect biodiversity?: One of the best ways to conserve forest biodiversity is to establish protected forest areas. But these areas must be of a certain size, or consist of a well-designed network of forest areas, to allow the local forest ecosystems to continue operating effectively. The forest surrounding the protected area must then be carefully managed so that it serves as a buffer zone. These surrounding forests also allow local communities to earn a livelihood without infringing on the protected forest. There have been numerous efforts aimed at safeguarding the world's biodiversity by protecting species in areas outside their original habitats. For example, seeds of some of the most economically important trees are being conserved in seed centers and gene-banks as a way of protecting their genetic diversity. But a large number of forest species have seed that do not survive storage, and many species of animals and plant-life are hard to protect once removed from their ecosystems.

Applications of Biotechnology in Forestry: Biotechnology provides important tools for the sustainable development of agriculture, fisheries and forestry, and can be of significant help in meeting an indispensable part in the rise of human civilization. It is

indeed often considered as one of the fields of scientific research in which the most rapid advances have been made in recent years. It includes the unique roles and functions that trees, major structural constituents of forest ecosystems have, their special biological characteristics, and their importance in the provision of environmental, social and economic goods and services. Forest trees have unquestionably entered the genomic era. Biotechnological tools viz., transgenic technology, RNA interference, functional genomics, marker assisted selection, QTL and tissue culture etc. have paved road for successful exploitation and integration of scientific fields with an increased sense of urgency for delivery of cutting-edge research in tree biotechnology, both in academia and industry. Advances and integration of such fields will have a great impact in many respects, and will continue to provide new information, thereby offering exciting prospects for future tree improvement programs worldwide.

Forest Biotechnology

The aim of the program is to support R&D projects on Forest Biotechnology with a focus on cutting-edge biotechnological interventions for forest and biodiversity conservation, optimal resource utilization and climate change mitigation, to encourage R&D programs in emerging areas of Forest Biotechnology aiming at conservation of forests; promoting sustainable use of bioresources, such as medicinal plants, tree-borne oil seeds, resin and wax yielding plants; developing tools for mitigation and adaptation of climate change impacts; and enhancing carbon sequestration by the forest vegetation using state-of-the-art biotechnological approaches.

Programme Type: Research and Development

Focus Area: Life Science and Biotechnology, , Forest Biotechnology, Earth, Atmosphere and Environment Sciences

Target Audience: Scientist and Researchers

Funding Agency: Department of Biotechnology (DBT), Govt. of India

Future Perspectives: Biotechnology application in forestry has made tremendous strides in the past decade. Many tree species engineered for expression of a variety of traits are already under extensive cultivation in many parts of the word. The status of biotechnology in India is very encouraging and the future back on with many opportunities. All modern biotechnologies require large research and development investments. The allocation of funds, through either private or public agencies, needs to achieve a balance between building scientific capabilities and knowledge and supporting more applied, well proven forestry technologies. From a genetic perspective, concerns that biotechnology is “unnatural” ignore the dynamic changes in the genetic code that occur within and across species genomes through modification of transposable genes or elements by virus vectors and through mutation. Tissue culture or genetically modified trees will be substantial managers with time to evaluate many of the issues being faced in agriculture, the economic realities of relatively long generations will continue to be a major challenge for investors in biotechnology in forest trees. It appears that genetic modification will therefore become a reality only for particularly novel and valuable traits in short

rotation species in intensively managed plantations. Other forest management decisions with potentially more serious ecological consequences, including large-scale species introductions or inappropriate use of provenances or improved trees from even conventional breeding, need to be evaluated by foresters, managers and regulatory agencies in the same way as the products of modern biotechnology. However, while those in the forefront of any technology will promote its potential benefits, in the end it will be the economic and regulatory systems of governing bodies at the national and global levels that must evaluate the technology's relevance and appropriateness.

Conclusion: This chapter has sought to address the main issues that should remain relevant to the use of any modern biotechnology in forestry, now and in the future. Many cultures have a powerful attachment to forests, and concern over their destruction has driven much of the growth of environmental groups. Their activities have done much to highlight the problems of deforestation worldwide, but the solutions they offer for stabilizing the world's wood supply have sometimes been less than helpful. For the world to be supplied with the wood it needs on a long-term sustainable basis, it needs to invest much more in the development of high-yielding, short rotation plantation forests. Biotechnology is essential to achieving this goal. The alternative is that the world's remaining natural forests will continue to be degraded, probably at an accelerating rate, and/or pollution from wood substitutes will increase. Those who oppose plantation forests either in any form, or the application of biotechnology to their development, need to be clear what the choices really are, rather than what they might like them to be. The logic of plantation forests is so strong that they will undoubtedly play a major role in achieving global sustainability. The only real question is how much more damage will be done to Earth's natural forests before the essential contribution of plantation forests is fully recognized. Genetic engineering is becoming a routine method in forestry. Although the possibilities in agriculture are much better because of the broader knowledge available and background breeding information, forest trees are also clearly in the focus of research. The ability to transfer genes into the genome of trees offers ample opportunities in the field of breeding research. Based on the Indian government's aim to enlarge the total area covered by forests to 23% by 2010 and to 33% by 2020, biotechnology is going to play a central role to tackle specific challenges. Trees are long living organisms and often surrounded by their wild relatives, which causes a risk of gene flow from transgenic stands into natural populations. Research is still needed to investigate the problems related to transgenic trees, e.g. concerning all aspects of biosafety including efforts to prevent the escape of transgenes into natural populations. Approval for the commercial use of transgenic trees and their easy vegetative propagation by cuttings (e.g. in poplar, Eucalyptus, casuarinas and Salix) can cause a rapid distribution of transgenic plant material in the near future.

2.7 Bioenergy

Bioenergy refers to renewable energy derived from biomass i.e. biological material directly or indirectly produced by photosynthesis. Biomass is available

in the form of forestry waste, residue from agricultural operation, processed waste from industry, municipal/urban solid waste. Bioenergy has been recognized as one of main sources of renewable energy. International Energy Agency (IEA) modelling indicates that modern bioenergy is an essential component of the future low carbon global energy system. India in its Nationally Determined Contributions (NDCs) stands committed to achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. Given India's agricultural strength and its vast biomass potential (annual biomass production of around 750 MMT & surplus biomasses of around 228 MMT) expansion of bioenergy sector has been identified as a key strategy in the country's transition to clean energy.

GoI Schemes (Source pib.nic.in):GoI's strategic efforts to advance the bioenergy sector are focused on reducing import dependence, saving foreign exchange, and promoting a circular economy. The government's strategy encompasses several vital areas, including ethanol and biodiesel blending, Compressed Biogas (CBG), Sustainable Aviation Fuels, biomass utilization (such as pellets and briquettes), Biohydrogen, and waste-to-energy solutions. The Ministry of New and Renewable Energy, GoI has notified the National Bioenergy Programme (NBP) for the period of FY 2021-22 to 2025-26 on 02.11.2022. The programme has been recommended for implementation in two phases with a total budget outlay of Rs 1715 Crore and a budget outlay of Rs 858 Crore has been allocated for the Phase-1. This programme has a provision of Central Financial Assistance (CFA) for various components related to Power generation, Biogas/BioCNG generation and Briquette/Pellet manufacturing, wherein Biomass is one of the major feedstock materials, which primarily shall be sourced from rural areas. The National Bioenergy Programme shall not only promote the utilization of surplus biomass but also provide an additional source of income for rural households.

Salient features and implementation mechanism of the National Bio Energy Programme

The National Bioenergy Energy Programme supports setting up of Bioenergy projects in the country under the following components:

- Waste to Energy Programme
- Biomass Programme
- Biogas programme

Waste to Energy Programme: The objective of this programme is to support setting up of waste to energy projects for generation of Biogas/ BioCNG/Power/producer or syngas from urban, industrial and agricultural wastes/ residues. The programme provides Central Financial Assistance (CFA) to project developers and service charges to implementing/ inspection agencies in respect of successful commissioning of Waste to Energy plants. The details of CFA for different components under this programme are as follows:

a. **Biogas generation:** ₹0.25 crore per 12000 cum/day (Maximum CFA- ₹5.00 crore/project)

b. **BioCNG/Enriched Biogas/ Compressed Biogas generation:** (Maximum CFA- ₹10 crore/project)

c. **BioCNG generation from new**

Biogas plant- ₹4.0 Crore per 4800 Kg/day;

d. **BioCNG generation from existing Biogas plant- ₹3.0 Crore per 4800 Kg/day.**

e. **Power generation based on Biogas (Maximum CFA- ₹5.00 crore/project)**

f. **Power generation from new biogas plant:** ₹0.75 Crore per MW

g. **Power generation from existing biogas plant:** ₹0.5 crore / MW

h. **Power generation based on bio & agro-industrial waste (other than MSW through incineration process):** ₹0.40 crore/MW (Maximum CFA - ₹5.00 Crore/Project)

i. **Biomass Gasifier for electricity/ thermal applications:** ₹2,500 per kWe with dual fuel engines for electrical application; ₹15,000 per kWe with 100% gas engines for electrical application; ₹2 lakh per 300 kWth for thermal applications.

Note: The eligible CFA would be 20% higher than Standard CFA pattern for (a) all plants in Special Category States (NE Region, Sikkim, Himachal Pradesh and Uttarakhand), Jammu & Kashmir, Ladakh, Lakshadweep and Andaman & Nicobar Islands, and (b) Biogas/BioCNG/ Power (biogas based) generation plants based on cattle dung as main feedstock set up by Gaushalas registered with respective State Government.

Biomass Programme: The objective of this programme is to support setting up of Biomass Briquette/Pellet manufacturing plants and Biomass (non-bagasse) based cogeneration projects in the country. This programme provides Central Financial Assistance (CFA) to project developers and service charges to implementing/inspection agencies for setting up of Biomass projects. The details of CFA for different components under this programme are as follows:

i. for Briquette/Pellet manufacturing plants: ₹9.00 lakh/ TPH (Maximum CFA- ₹45.00 Lakh per project).

ii. for Non-Bagasse Cogeneration Projects: ₹40 lakh/ MW (Maximum CFA- ₹5.00 Crore per project).

Biogas Program: The objective of this programme is to support setting up of biogas plants for clean cooking fuel, lighting, meeting thermal and small power needs of users which ultimately results in GHG reduction, improved sanitation, women empowerment and creation of rural employment. The details of Central Financial Assistance (CFA) for different components under this programme are as follows:

a. for small biogas plants (1-25 cubic meter/day plant capacity): ₹9800/- to ₹70,400/- per plant based on size of the plant in cubic meter;

b. for Power generation and thermal application (25-2500 cubic meter/ day plant capacity): ₹35,000/- to ₹45,000/- per kilowatt for power generation and ₹17,500 /- to ₹22,500/- per kilowatt equivalent for thermal applications (The eligible CFA would be 20% higher than Standard CFA for NER, Island, Registered Gaushalas and SC/ST beneficiaries).

Ethanol blending program: Since its inception, the ethanol blending percentage has surged from 1.53% in 2014 to 15% in 2024. GoI has set an ambitious target of reaching 20% blending by 2025.

Over the past decade, this initiative has delivered significant benefits, including saving ₹99,014 crore in foreign exchange, reducing CO2 emissions by 519 lakh metric tons, and substituting 173 lakh metric tons of crude oil. Furthermore, the program has had a considerable economic impact, with Oil Marketing Companies disbursing ₹1,45,930 crore to distillers and ₹87,558 crore to farmers. Notably, two second-generation (2G) refineries have been established in Panipat and Numaligarh to convert agricultural residues like Parali and bamboo into ethanol. These refineries are instrumental in reducing pollution and bolstering energy security while transforming farmers into "urjadata" or active contributors to the energy sector. To support the ethanol industry, the Government of India has introduced various incentives for ethanol production. These include ₹9.72 per litre for ethanol derived from maize, ₹8.46 per litre for ethanol from damaged rice, and ₹6.87 per litre for ethanol from C-heavy molasses. These incentives have significantly boosted maize's contribution to ethanol production, which has risen to 36% in the 2023-24 Ethanol Supply Year (ESY) from a mere 0% in 2021-22. Additionally, government has resumed the supply of FCI rice to ethanol distilleries, allowing for the purchase of up to 23 lakh tonnes through e-auctions from August to October 2024. Starting from November 2024, the supply of sugarcane juice and syrup to distilleries will also commence, marking the start of the 2024-25 Ethanol Supply Year. Government of India has also emphasized the importance of diversifying feedstocks used for ethanol production to ensure security and avoid over-reliance on any single source. The government's ongoing policy of providing stable and remunerative prices for ethanol has effectively reduced pending arrears for sugarcane farmers, lessened crude oil import dependence, and contributed to foreign exchange savings while benefiting the environment.

Government initiatives

- The Ministry of Petroleum and Natural Gas has launched the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative in October 2018 which assures offtake of BioCNG/Compressed Biogas (CBG) after purification through Oil Marketing Companies (OMCs) for sale as automotive fuels.
- Under the GOBARDHAN scheme implemented by Department of Drinking Water and Sanitation, Ministry of Jal Shakti, a financial assistance upto ₹50.00 lakh per district is available for setting up of community biogas plants in villages, blocks / district.
- Ministry of Power has notified SAMARTH Mission (National Mission on Use of Biomass in Thermal Power Plants) for promoting the blending of biomass in the existing coal powered thermal power plants.
- Central Pollution Control Board, Ministry of Environment, Forest and Climate Change has notified guidelines to provide financial support for setting up of Biomass Pellet plants in the NCT of Delhi, states of Punjab and Haryana and NCR districts of Rajasthan and Uttar Pradesh.

The Department of Biotechnology has established following Bio-

energy Centres:

- DBT -IOC Centre for Advanced Bio-Energy Research, Faridabad
- DBT Pan IIT Center for Bioenergy
- DBT-TERI Center of Excellence on Integrated Production of Advanced biofuels and Bio-commodities, The Energy and Resources Institute, New Delhi
- DBT- ICGEB Centre for Advanced Bio-Energy Research, New Delhi
- DBT-ICT Centre for Energy Biosciences, Mumbai

Main objectives of above Bio-energy Centres are:

- To conduct multi-disciplinary bio-energy research involving biology, chemical science and material science etc.
- To develop technology for second generation biofuel.
- To deploy bio-fuel technologies with existing capabilities to scale up.
- To perform cutting edge research using Synthetic and Systems biology approaches towards the development of novel technology for bio-fuel production.

There are 47 Thermal Power Plants which have carried out co-firing of agro residue-based biomass pellets with coal. The Ministry of Power issued modification on 16.06.2023 to revise the biomass policy dated 08.10.2021 and now it mandates 5% biomass co-firing in Thermal Power Plants (TPPs) from FY 2024-25. This obligation shall increase to 7% from FY 2025-26.

Government has taken many initiatives to ensure the availability and procurement of biomass pellets for co-firing in TPPs like, Finance Assistance Schemes by MNRE and CPCB have been issued for biomass pellet manufacturing units, Reserve Bank of India (RBI) has approved 'Biomass pellet manufacturing' as an eligible activity under Priority Sector Lending (PSL), Procurement Provision of Biomass Category has been created on GeM portal, Revised Model long term contract for Biomass supply was issued by Ministry of Power, Vendor database finalized and listed on SAMARTH website, awareness programmes & Advertisement Campaign were carried out, Provision of Udyam Aadhaar on National Single Window System, Bankable Model Project Report for Biomass Pellet Plants etc. Further, the Ministry of Power through a policy Addendum dated 03-05-2023 has indicated the various type of various agro residues such as stubble/straw/stalk/husk which are surplus and not being used as animal fodder for making the biomass pellets. This includes agro residue obtained from crops like Paddy, Soya, Arhar, Gwar, Cotton, Gram, Jawar, Bajra, Moong, Mustard, Sesame, Til, Maize, Sunflower, Jute, Coffee, etc. as well as Groundnut Shell, Coconut Shell, Castor Seed Shell etc.

In addition, pellets made from the following agro product/crop/waste can also be used for co-firing in TPPs viz. Bamboo and its by-products, Horticulture waste such as dry leaves and trimmings obtained from maintenance & pruning of trees and plants and other biomass such as Pinecone/Needle, Elephant Grass, Sarkanda, etc. As per GoI figures, 1,64,976 Metric Tonnes of agri residues-based biomass has been co-fired in 47 coal based thermal power plants till May 2023.

Annexures on State-wise details:

Annexure II: State-wise details of Bioenergy plants established in past five years (from FY 2017-18 to FY 2021-22) in the country

Annexure III: State-wise details of Biomass Power and Bagasse/Non-bagasse cogeneration projects installed in the country upto March 2023

Annexure IV: State-wise details of Biomass usage in all TPPs in the country till May' 2023)

Potential technologies under development @ DBT/CSIR (Source DBT website)

Anaerobic Gas Lift Reactor (AGR) technology: CSIR-IICT has developed a novel Anaerobic Gas Lift Reactor (AGR) technology to generate biogas and bio manure from biodegradable organic wastes. The AGR technology works on a high rate biomethanation process suitable for operation in Indian conditions. The biogas can be utilized for combined heat and power applications, while the biomanure rich in nutrients can be applied in farms to increase the fertility of the soil for improved crop yield. The AGR technology helps reduce GHGs (greenhouse gases) and avoids the diversion of waste to landfills resulting in a cleaner environment. It is a promising method to treat biodegradable waste in-house in a scientifically safe manner and generate green energy.

2G- Ethanol production and Enzyme development technologies: 2G Ethanol can be produced from farm waste such as left over after agricultural waste. Such lignocellulosic waste is being used for production of Ethanol that can then be mixed with conventional fuels. 2G ethanol bio-refineries may significantly contribute towards the Ethanol Blending Programme for achieving 20% Ethanol Blending in Petrol and reducing consumption of fossil fuels eventually. DBT-IOC Centre for Advanced Bioenergy Research IOCL, Faridabad and DBT-ICGEB Centre for Advanced Bioenergy Research, ICGEB New Delhi has done remarkable work in the area of 2G Ethanol production. DBT-ICGEB Bioenergy Centre has led the enzyme production technologies that are being tested at commercial level. Centre has reached the TRL level 4/5 of the technology and is continuously working for further improvement. DBT-IOC Bioenergy Centre has planned to go for integrated demonstration plant of 10TPD (dry biomass basis) with onsite enzyme production to establish process at higher scale, before going for the commercializing of indigenous 2G ethanol technology.

Waste to Energy: Organic waste is the major sources green has house gas emissions in the atmosphere. To utilize these wastes as resources for energy production is a huge contribution to combat climate change. GHG emissions into the atmosphere could be reduced by utilizing the organic waste as resource for the generation of biogas and bio manure instead of landfilling. One ton of organic waste could release about 280-296 kg of CO2 into the atmosphere per day, but due to the installation of decentralized biogas plants at waste generation source, CO2 is captured along with CH4 and utilized as fuel. Reduced carbon footprint and pollution due to land filling is mitigated

Algal biofuels and value-added productions: Algae have the potential

to utilize the atmospheric Carbon dioxide as well as the lipids and biomass of algae is being used for biofuels and other bio-based values added products. This would lead to significant reduction GHG in atmosphere as well as reduced dependency on chemical-based products that cost huge environment impact and contribution to climate change.

The Energy and Resource Institute, New Delhi under DBT-TERI Centre of Excellence- 'Integrated Production of Advanced Biofuels and Bio-commodities has demonstrated marine algae cultivation in 1,00,000 L scale (panning across 220 sq. meter area) in outdoor (Mumbai coast) using a custom-made sunlight-distributed algal growth system. The system uses select marine algal strains with self-aggregation features that facilitate a simple and low energy intensive harvest method in the growth system itself (sweeping collection mechanism of algae that settle at the bottom in 30-45 minutes). This technology has been demonstrated in pilot scale (100 L scale)

Carbon Dioxide to high value lipids technology: DBT IOC Centre has developed a novel technology to convert carbon dioxide into acetic acid and Centre's aerobic fermentation technology to convert acetic acid to lipids (algal oil) including highly valuable Omega 3-fatty acids (DHAs) & biodiesel. The centre has put up world's first pilot facility at IOC R&D, Faridabad to sequestrate about 10 kg/day of CO2. The conversion of CO2 to acetates and then omega 3 rich lipids through algae is a potential game changer technology. This technology decouples commodity chemical production from commodity feedstocks. That also lead to utilizations of Carbon dioxide.

Biohydrogen Production from biomass: The team of DBT-IOCL Bioenergy Centre, Faridabad has developed H2 production from biological source or through biological methods is considered as biohydrogen which is more sustainable than conventional methods. Hence, biological H2 production processes are gaining much more importance particularly dark fermentation process. The sugars to be utilized are proposed to be derived from biomass which is renewable feedstock in this proposal using anaerobic microbes

Feedstock Development: Exploring alternative feedstock for bio-energy production is also a significant area in which Department of Biotechnology (DBT) is taking initiative towards generating green fuels as well reduce the dependency on fossil fuels. Modifying the lignin composition in biomass sorghum and its deployment for enhanced ligno-cellulosic (2G) biofuel production - This project aims to assess and deploy low-lignin (optimized) biomass sorghum lines Pyramided with bmr 6 and 12 genes and showing high biofuel production potential, reduce (optimize) lignin content and improve its composition using gene editing, comparative analysis of biofuel production potential in low-lignin sorghum lines (1) pyramided with bmr6/bmr12 and (2) optimized with genome editing technology.

Carbon Capture & Utilization: Carbon Capture and Utilization has been the significant area which intended to directly utilize the atmospheric Carbon and utilization it for the production/ synthesis value added products. The

following areas are covered through DBT funded projects

- Bioconversion of CO2 to Biofuels through Microbial Catalyzed Systems.
- Solar assisted hydroformylation/ carboxylation of olefins containing natural products with CO2
- Sequestration of CO2 with Simultaneous Production of Succinic Acid by metabolically engineering
- Metabolic engineering of cyanobacteria for photosynthetic conversion of carbon dioxide into storable fuels
- Demonstration of algal chassis for the photo autotrophic production of isoprenoids
- Integrated Design and Demonstration of Intensified CO2 Capture with cost effective advanced Process

2.8 Biotechnology and IoT

The interaction between the fields of biotechnology and information technology has led to the creation of a new segment called BioIT. The emergence of the segment can be attributed to the need for technology to make sense of the data that is being generated by hospitals, R&D labs, clinics etc. The volume of the data is increasing exponentially. The segment, based on advances in computing and data science, extracts knowledge from biological data. It includes the collection, storage, retrieval, manipulation and modelling of data for analysis, visualization or prediction through the development of algorithms and software. Bio- IT For a thriving bioinformatics segment, a superior IT sector is required, and India already has an established IT sector with State-of-the Art facilities. Centre for Development of Advanced Computing, under the Ministry of Electronics and Information Technology, has created computing capacity through introduction of PARAM-Biochrome and Bio Blaze. These are advanced computing technology designed specifically to handle areas such as computational biology. This data has the potential to be used for national and regional development and can be used to address the poorest and the marginalised groups to ensure that "no one is left behind". It can be used to measure and track progress on the different development goals. The big data analytics can also develop high impact solutions that be used for development purposes. The public private partnerships play a key role in this segment to ensure that the data is available across industries for research and development purposes. However, it would be important to ensure that while unlocking the value of data the parties are not violating human rights

Artificial intelligence (AI) has gained increasing attention in bioinformatics and computational molecular biology research.

i. To solve several problematic aspects that occur in the arena of bioinformatics, advanced artificial intelligence technology is required.

ii. Recent approaches and applications of AI and Machine Learning methods have proven to be more useful for genome and gene editing, cancer drug discovery classification, protein folding algorithms, and more.

iii. The IoT has promising applications

in remote patient monitoring, intelligent sensor monitoring, and medical device management

iv. Deep learning, widely used in image processing, is one of the most popular approaches to artificial intelligence and can be applied to bioinformatics.

v. Translational bioinformatics is an emerging field that relies on biological, predominantly medical data, to study disease and its behaviours.

vi. IoT is widely used in animal healthcare, for example, to sense and monitor blood sugar levels, heart disease diagnosis, artificial heart valve and pacemaker monitoring, cancer diagnosis, etc.

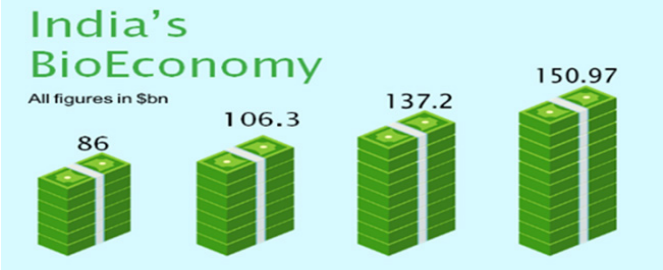
vii. In India, real-time, multi-dimensional data about each patient collected from IoT devices can be analyzed using bioinformatics tools and methods to provide more personalized and timely patient care.

viii. In India, AI technology has been widely utilized in biological studies for calculation and sighting. With the expending, the accessibility of dissimilar types of biological database, Biological Information Exploring, Biological Sequence Matching, and the application of artificial intelligence, especially machine learning techniques, has become recurrent.

03 Policy initiatives & Institutional Arrangements

The world is at the cusp of a new industrial revolution driven by bio-innovation. Given that biotechnology will strongly influence future bio-based manufacturing, many nations like the United States of America, Japan, Australia, Finland and European countries, have put forward their policies, strategies and roadmaps to set up a robust framework for biomanufacturing.

It has been estimated that India is on the verge of a biotech revolution that will shape the future, with our nation leading the charge. Over the past decade, India's BioEconomy has grown significantly, from $10 billion in 2014 to $151 billion by the end of 2023. It is expected to reach $300 billion by 2030 while growing at a CAGR of ~17%. The key growth drivers have been Government support (Make in India, Startup India, Atmanirbhar Bharat Abhiyan etc.), Research and development capability and demographic advantage (skilled workforce). This growth highlights the sector's increasing significance as it now accounts for 4.25% of India's Gross Domestic Product (GDP) of $3.55 trillion in 2023 calendar year. (India Bioeconomy Report, 2024, BIRC, https://birac.nic.in/webcontent/ IBER_2024.pdf).



India's BioEconomy spans several key subsectors, each contributing significantly to national growth through biotechnology.

BioIndustrial
(48.09% Share, $72.6 Billion)

The BioIndustrial segment, representing nearly half of the total BioEconomy, is valued at $72.6 billion. Its dominance reflects the growing adoption of bio-based solutions across sectors such as biofuels, chemicals, bioplastics, and enzymatic applications in various industries. The push toward sustainability and green technology has positioned this segment as a cornerstone of India's BioEconomy.

BioPharma
(35.65% Share, $53.8 Billion)

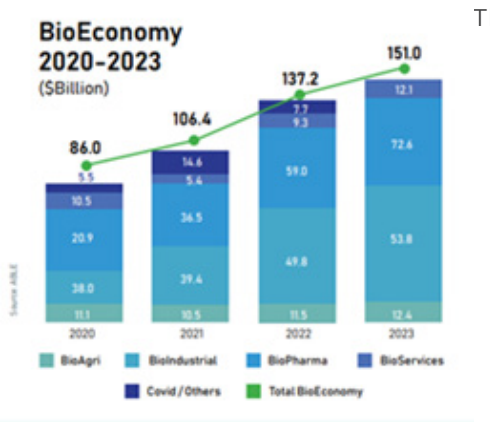
With a significant 35.65% share, valued at $53.8 billion, this segment is crucial to healthcare and medical innovation. BioPharma's focus on pharmaceuticals, medical devices, diagnostics, and biologics emphasizes India's growing role as a global leader in affordable biopharmaceuticals.

BioAgri
(8.24% Share, $12.4 Billion)

Contributing 8.24% to the total BioEconomy, BioAgri centers on agricultural biotechnology. Valued at $12.44 billion, this segment enhances agricultural productivity and resilience through genetically modified crops like Bt Cotton and precision agriculture technologies.

BioIT/Research Services
(8.02% Share, $12.1 Billion)

This segment, valued at $12.1 billion, includes contract research, clinical trials bioinformatics, biotech software, and bioeducation. It reflects India's growing stature as a global hub for research and development services, offering cost-effective solutions in drug discovery and data management.



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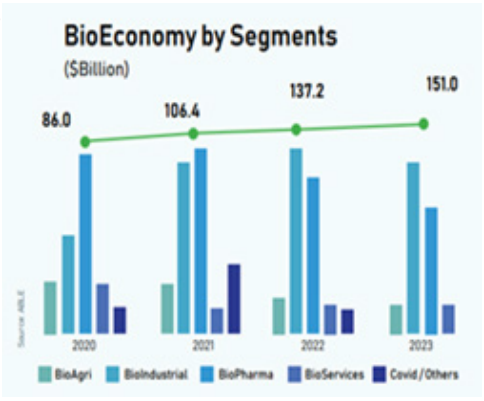
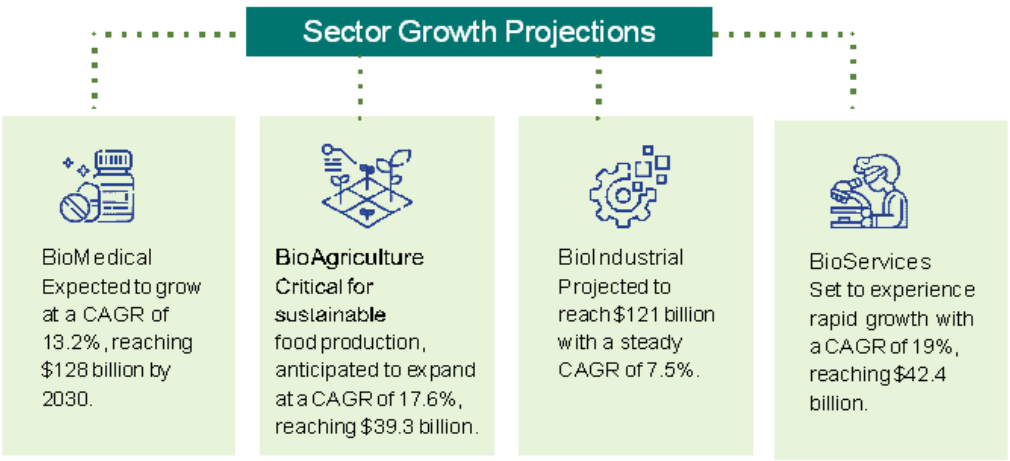


BioEconomy contributes significantly to various national economies, with Italy and Spain leading with 22% of GDP. The U.S. and China, having larger BioEconomy sizes, see lower GDP shares at 5% and 4%, respectively. India's BioEconomy share aligns with China at 4.25%. By 2050, the global BioEconomy is expected to expand significantly, with its contribution to the world economy growing from $4 trillion to $30 trillion, representing nearly 12% of the projected global GDP of $228 trillion. Emerging markets like India, China, and Indonesia are anticipated to be key drivers of this growth. According to projections from Goldman Sachs, visualized by Visual Capitalist, India's real GDP is estimated to reach $30 trillion, while China's GDP could rise to $42 trillion and the United States to $35 trillion by 2050. For India, with its GDP projected at $22 trillion, the BioEconomy's contribution could range between $1.4 trillion and $2.7 trillion, accounting for 6.5% to 12% of the nation's GDP. This growth is poised to play a critical role as India and other nations work toward achieving net-zero carbon emissions, with sustainability initiatives expected to drive economic growth and create millions of high-quality jobs. The future of India's BioEconomy looks exceptionally promising, with substantial growth anticipated across key sectors. By 2030, the India BioEconomy is projected to double to $300 billion, up from $151 billion in 2023, reflecting a robust CAGR of 12.3%.



3.1 Bioeconomy Policy

On 31st August 2024 the GoI released the new Bioeconomy policy called BioE3 i.e., Biotechnology for Environment, Economy, and Employment. The policy is aimed at 'Fostering High Performance Biomanufacturing' aligned with National initiatives of the government of India such as 'Net Zero' carbon economy and Mission LiFE (Lifestyle for environment). The policy has 6 themes viz., 1. Bio-based chemicals and enzymes; 2. Functional foods and Smart proteins; 3. Precision biotherapeutics; 4. Climate resilient agriculture; 5. Carbon capture and its utilisation; 6. Futuristic marine and space research. Other key aspects of the BioE3 policy include innovation-driven research and development and entrepreneurship across various thematic sectors to expedite the commercialization of technology through establishment of bio-manufacturing and bio-foundry and bio-AI hubs. The BioE3 Policy will facilitate sustainable and efficient utilization of biological resources through scientific knowledge for innovation, scaling-up and biomanufacturing of specialty chemicals, enzymes, biopolymers, functional foods, smart proteins, veterinary products, precision biotherapeutics and services. The carbon capture storage to biomass and utilization thereof by converting it to fuels and chemicals through biological systems are essential in meeting the Net Zero targets.

As regards agriculture - to enhance agricultural productivity from reduced land mass, amidst climate change impact, there is a need to promote soil microbiome-based research in India including soil microbiome/genome analysis, selection process for superior microbial phenotypes, process for shifting the microbial community composition towards the desired/ most beneficial microbial consortia, developing crop specific products for crop nutrition & protection, and product formulation for enhanced stability. This Policy will enable fundamental goal of food security through innovations for climate smart agriculture for production of improved crop varieties to address agrarian and nutritional challenges and traits for climate adaptation and mitigation. As we are aiming at 45% reduction in emission intensity by 2030 and taking steps towards achieving Net Zero by 2070, the Policy will facilitate de-carbonization from the hard-to-abate industry sectors which also includes microbial conversion of captured CO2 into industrially relevant compounds. The proposed inter-ministerial collaboration in various areas is indicated in the table below.

S. No	Ministries/ Departments	Proposed Inter-Ministerial Collaborations
1.	Ministry of Electronics and Information Technology	• To provide computational and AI support for modelling of the biomanufacturing process • Setting up of Bio-AI Hubs to support process innovation for rapid design, testing and engineering of microorganisms needed for scaling-up of bioprocesses
2.	Indian Council of Agricultural Research	• Collaboration projects for the development, field trials and regulatory approval of emerging Agribiologicals including Biofertilizers, Biostimulants and Biopesticides
3.	Ministry of New and Renewable Energy	• To ensure biomass supply chain, its management, and resource availability forecasting for future, using AI/ML/GIS/RS tools. • Initiate collaborative projects on Carbon Capture and its Utilization
4.	Department of Space/ Indian Space Research Organization	• Collaborative experiments and studies under Joint ISRO-NASA Mission to International Space Station • Collaborative experiments and studies in human space flight missions under "Gaganyaan" program and proposed Bharathiya Antariksha Station
5.	Department for Promotion of Industry and Internal Trade	• Startup India under DPIIT has a wide incubator network and over 160 seed-funded incubators. DBT will collaborate with Startup India for building the operationalization and business workflow for the hubs, along with building industry networks.
6.	Department of Chemicals and Petrochemicals	• DBT will collaborate with this Department for shortlisting of high- value Chemicals /APIs/ Enzymes to be biomanufactured
7.	Ministry of Health and Family Welfare (FSSAI)	• Working with FSSAI, MoH&FW to streamline regulatory approvals for Smart Proteins and Functional Foods.
8.	Ministry of Health and Family Welfare (Central Drugs Standard Control Organization)	• Setting up of GMP grade facilities for Precision Biotherapeutics including Monoclonal Antibodies, mRNA Therapy and Cell & Gene Therapy
9.	Department of Pharmaceuticals	• Specific collaboration with NIPERs for the development of APIs • Fermentation-based bulk drugs under Production Linked Incentive (PLI) Scheme for Bulk Drugs implemented by the DoP will be taken up • Scheme for Biotherapies like Cell & Gene therapy, Immune Therapy, etc.
10.	Ministry of Earth Sciences	• Dovetailing of DBT's Marine Biomanufacturing initiatives with MoES 'Deep Ocean Mission' and 'Blue Economy'
11.	Department of Science and Technology	• Collaboration with DST under its programme on 'Advanced Manufacturing Technologies'
12.	Council of Scientific and Industrial Research	• Establishing collaborations with CSIR labs for biomanufacturing of Bio-based chemicals, APIs, Bioplastics and Enzymes
13.	Indian Council of Medical Research	• Precision Biotherapeutics including Monoclonal Antibodies, mRNA Therapy, Cell and Gene Therapy
14.	Ministry of External Affairs (NEST Division)	• Fostering international cooperation, collaboration and knowledge exchange with foreign countries and in multilateral institutions to advance India's national interests
15.	Defence Research Development Organization	• Biopolymers, and space food research

In the interim budget presented before the elections, Finance Minister Nirmala Sitharaman had mentioned about "a new scheme of bio-manufacturing and bio-foundry to provide environment-friendly alternatives such as biodegradable polymers, bioplastics, bio-pharmaceutical and bio agri-inputs". As per Union Minister for Science and Technology Dr. Jitendra Singh "the future economy of the world is largely going to be bio-driven and India has the opportunity to take the lead in the bio revolution of the 21st century. Just as the IT-driven industrial revolution of the 1990s was led by the West, India can lead the next bio-driven revolution because it stands at an advantageous position not enjoyed by the West as far as the bio-resources and bioeconomy is concerned" (https://www.theweek.in/news/biz-tech/2024/08/31/decoding-indias-new-bio-e3-policy-will-it-be-game-changer-in-mission-2047.html).

Biofuel Scheme: In a major move to boost India's biofuel production and reduce reliance on fossil fuels, the Union Cabinet on August 9, 2024, approved the modification of "Pradhan Mantri JI-VAN Yojana" (Jaiv Indhan- Vatavaran Anukool fasal awashesh Nivaran). The scheme will cover advanced biofuels produced from lignocellulosic feedstock, i.e., agricultural and forestry residues, industrial waste, synthesis (syn) gas, algae, and others, expanding its scope and extending its timeline to 2028-29. The scheme will provide financial incentives to projects using new technologies and innovative approaches in biofuel production. The government has been steadily increasing ethanol blending in petrol to reduce the country's dependence on imported crude oil. The expanded Pradhan Mantri JI-VAN Yojana is expected to further accelerate this process and contribute to India's target of net-zero greenhouse gas emissions by 2070. The Government has been promoting blending of ethanol in petrol under the Ethanol Blended Petrol (EBP) Program, where Public Sector Oil Marketing Companies (OMCs) sell petrol blended with ethanol. Under the EBP Program, the blending percentage has touched 15.83% in July 2024. OMCs are on course to achieve the 20% blending target by the end of Ethanol Supply Year 2025-26. It is estimated that over 1,100 crore liters of ethanol will be required during ESY 2025-26 to achieve 20% blending, for which 1,750 crore liters of ethanol distillation capacity needs to be installed to meet the blending requirement and for other uses (potable, chemical, pharmaceutical, etc.). To meet the ethanol blending targets, the Government is also focusing on alternate sources like 2nd Generation (2G) Ethanol (Advanced biofuels). Surplus biomass or agricultural waste with cellulosic and lignocellulosic content, industrial waste, etc., can be converted to ethanol using advanced biofuel technology. Under the scheme, the first 2G Ethanol Project set up by Indian Oil Corporation at Panipat, Haryana, was dedicated to the nation by the Prime Minister on August 10, 2022. The other 2G commercial projects being set up by BPCL, HPCL, and NRL at Bargarh (Odisha), Bathinda (Punjab), and Numaligarh (Assam), respectively, are also nearing completion (https://ableindia.in/news/details/cabinet-gives-green-signal-to-expanded-biofuel-scheme)

Golden Jubilee Biotechnology Park for Women: The 20-acre Golden Jubilee Biotech Park near Chennai, the first of its

kind dedicated to women entrepreneurs in life sciences, has created over 500 women-led startups and trained 10,000 women scientists in the last 20 years since its inception. Established in 2001, the Park is a unique venture between the Government of Tamil Nadu, the Department of Biotechnology (DBT) of Government of India and the M S Swaminathan Research Foundation. The Park currently houses 25 women-led companies that clock over Rs 100 crore in turnover annually. These companies employ 1,000 people directly and provide employment to at least 10,000 people indirectly. The latest addition to the Park is BioNest, a state-of-the-art, 5,000 sq.ft co-working space with plug-n-play facility that allows innovative women entrepreneurs to establish quickly the 'proof of concept' of their innovative ideas that can ultimately lead to product commercialization. The Park, run by the Golden Jubilee Biotech Park Society, is a first of its kind integrated model in the country from R&D to manufacturing facility under one roof. Since inception Park is committed to encourage and empower Women Entrepreneurs who are in the Biotech, Life Science stream from across country and especially from Tamil Nadu. The Park has 20 Unit modules each of 1000 sq.ft., offers entrepreneurs the scaling up possibility. Furthermore, dedicated parcels of 0.25 acres of land available for setting up own manufacturing unit for large scale production. The Park has been recognized by BIRAC – DBT – Govt., of India, and granted Seed Fund of Rs.2.00 crores to support the qualifying early-stage startups on an equity basis.

Recent Policy Reforms:

- The Department of Biotechnology (DBT) has successfully executed the rationalization of autonomous bodies, subsuming 14 institutes under the Biotechnology Research and Innovation Council (BRIC). This restructuring aims to centralize governance for maximum impact in biotech research across India.
- **Biofuel Policy:** Introduction of biofuel policies promoting 10% and 20% blending of ethanol with petrol.
- **Startup Support:** BIRAC's support for over 4500 startups, entrepreneurs and government-backed development of over 750 products.
- **Product Linked Incentives (PLI):** Schemes incentivizing the production of pharmaceutical products within India.
- **Regulatory Advancements:** Formulation of globally acclaimed Biosimilar guidelines and gene editing guidelines.
- **Mission-Oriented Approach:** Launching of the National Biopharma Mission for indigenous vaccine development and the National Medical Devices Policy 2023.
- **Strategic Vision:** Unveiling the National Biotechnology Development Strategy 2020-2025, aiming for India's recognition as a Global Biomanufacturing Hub by 2025.
- **Strengthening Intellectual Property Guidelines:** In September 2023, The Department of Biotechnology (DBT), in consultation with stakeholders, has notified Intellectual Property (IP) guidelines

to facilitate seamless transfer of IP from research organizations to commercialization, thereby enhancing societal impact. It aims to streamline the transfer of IP from institutes to commercialization, fostering technological innovation for larger societal impact.

- **Policy Framework on Biomanufacturing:** A major initiative has been launched to promote high-performance Biomanufacturing, fostering innovation, scale-up, and manufacturing facilities for bio-based commercial products. This initiative is expected to drive growth in India's Bioeconomy. This is a bid to capitalize on India's burgeoning bioeconomy set to reach $300 bn by 2030 and align with the vision of Green Growth outlined in the Union Budget 2023-2024. The Department of Biotechnology (DBT) is spearheading a pioneering initiative. Termed "Fostering High Performance Biomanufacturing: An Integrated Approach towards Promoting Circular Economy for Green, Clean, and Prosperous India,"
- **Streamlining Regulatory Approval Processes:** DBT has launched the Biological Research Regulatory Approval Portal (BioRRAP), simplifying regulatory approval processes for biological research activities in India, fostering ease of scientific research. BioRRAP provides a single route to direct the applicant to regulatory agencies providing requisite approval relevant to the biological research.
- **Guidelines for Research on Genetically Engineered Insects:** In compliance with the "Rules for the Manufacture, Use/Import/ Export and Storage of Hazardous Microorganisms/ Genetically Engineered Organisms or Cells 1989," established by the Ministry of Environment, Forest and Climate Change (MoEF&CC), the Government of India regulates all activities concerning Genetically Engineered (GE) organisms and hazardous microorganisms. Recognizing the diverse applications of genetic engineering in insects and the need for stringent biosafety measures, the "Guidelines and Standard Operating Procedures for Research on Genetically Engineered Insects, 2023" have been meticulously crafted. These guidelines ensure the safety of organisms and the environment while maximizing the benefits of genetic engineering.
- **National Green Hydrogen Mission:** The Ministry of New and Renewable Energy's ambitious National Green Hydrogen Mission, sanctioned by the Union Cabinet on January 4, 2023, with a budget of ₹19,744 crore ($2.4 Billion), is rapidly advancing towards its objectives. A pivotal financial measure under the Mission, the Strategic Interventions for Green Hydrogen Transition (SIGHT) Programme, with an allocation of ₹17,490 crore ($2.1 billion), aims to bolster domestic manufacturing of electrolysers and the production of Green Hydrogen.

Key trends:

- o India's BioEconomy is advancing rapidly with breakthroughs in gene therapy, diagnostics, and biomanufacturing. The country's

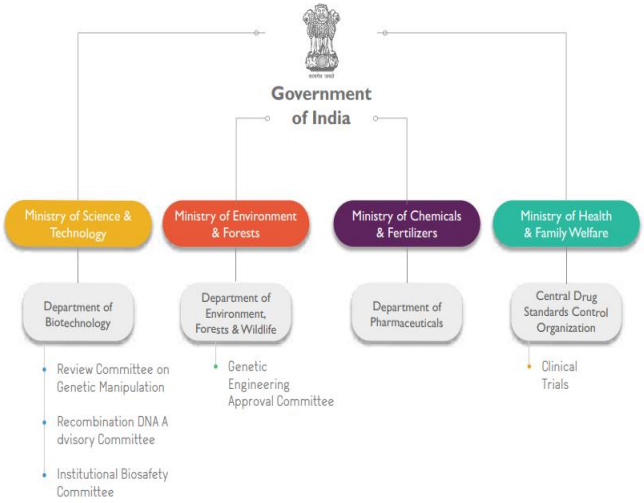
focus on self-reliance is driving innovations in vaccines and biotech, reshaping its economic and healthcare landscape through significant local research and development.

- India's biotech startup sector continues its rapid ascent, with the last three years showcasing exponential growth. Between 2021 and 2023, the cumulative number of biotech startups surged from 5,365 to 8,531—a 59% increase. This rise reflects a consistent upward trajectory since 2016, with a noticeable surge post-2020. The biotechnology and life sciences sector added 1,128 startups in 2021, followed by 1,390 in 2022, and a record-breaking 1,776 in 2023. This expansion is driven by increased investments, favorable policy shifts, and rising demand for biotech innovations in healthcare and sustainability. Complementing this expansion, the number of biotech startups in India is expected to surge from 8,531 in 2023 to an impressive 35,460 by 2030. This growth will significantly boost employment, with the BioEconomy projected to create 35 million jobs.
- As regards crop improvements, ADVIKA (NC 7) a drought tolerant chickpea variety developed through genetic introgression, offering 7% higher yield under drought conditions has been approved for nationwide cultivation. It is specifically suited for India's Central Zone. The Punjab Agricultural University has enabled 'AccelBreed facility' that enables speed breeding with precise environmental control, accelerating crop development.

Future of Bioeconomy: BioEconomy Set to Surge from $4 Trillion to $30 Trillion by 2050, Transforming the Global Economic Landscape. This dramatic increase will reshape economic frameworks, emphasizing the BioEconomy's crucial role and its capacity to drive innovation and sustainability across industries. Indian BioEconomy is poised for continued growth. Collaboration between academia, industry, and policymakers will be crucial to harness the full potential of this sector. Continued investment in research and development, coupled with robust regulatory frameworks, will drive innovation and ensure the BioEconomy thrives in a sustainable and equitable manner. The BioIndustrial segment presents a significant opportunity to address climate change through the development and widespread adoption of bio-based materials. The BioPharma sector holds the promise of personalized medicine and more effective treatments for various ailments. BioAgri offers a path towards sustainable food production and improved food security for a growing global population. BioIT / Research Services / BioServices will continue to be the engine driving innovation across the BioEconomy. In conclusion, the BioEconomy is experiencing a period of remarkable growth (Indian BioEconomy Report, 2024, BIRAC). As per Sh. Rajesh Gokhale, Secretary, DBT the government aims to reduce dependence on petrochemicals in multiple sectors and attract over ₹10,000 crore investments through BioE3 (https://www.livemint.com/news/ india/india-to-launch-bio-e-3-policy-to-attract-10k-cr-investment-11680112438283. html).

3.2 Institutional Arrangements and support

Public Sector Undertakings: The Indian biotechnology industry is regulated by four main bodies – Ministry of Science and Technology, Ministry of Environment and Forests, Ministry of Chemicals and Fertilizers and Ministry of Health and Family Welfare. The application policies concerning various above agencies often cause problems. Since different agencies are under different ministries, seeking approvals requires coordination from all the concerned ministries. The coordination between all departments and ministries hasn't been as strong as it should be. This often delays the rate of approvals and creates challenges in tracking of applications. Figure below represents the division of departments concerning biotechnology amongst various ministries.



The Department of Biotechnology under the Ministry of Sciences and Technology reviews issues related to genetic manipulation via the Review Committee on Genetic Manipulation. The committee covers the area of research as well as largescale handling of hazardous microorganisms, Genetically Engineered (GE) organisms or cells and products thereof. While this particular committee overviews multiple stages of development of GE organisms; its approval is carried out by another committee. Genetic Engineered Approval Committee (GEAC) under the Ministry of Environment, Forests and Climate Change have the responsibility concerning appraisal of activities involving large scale use of hazardous microorganisms and recombinants in research and industrial production with a perspective of their environmental impact. The committee also shares the responsibility for appraisal of proposals relating to the release of GE organisms and products into the environment including experimental field trials.

Therefore, in case of GE organisms, from its approval to its review, an applicant will have to move between two different ministries and two different departments. In such a situation, the applicant is dependent on smooth cooperation between the departments and the ministries. This could delay the process regarding use and commercialization of GE organisms. There is a need to increase coordination between the departments and ministries to fasten the rate of assessment of applications.

Public Sector Undertakings: The list of Public Sector Undertakings and Autonomous institutions involved in Biotechnology Research and innovations are indicated in Annexure 4.

Biotech Science Clusters: India has emerged as a significant player in the biotechnology sector, with numerous Biotech Science Clusters across the

country.

1. Bangalore Biotech Cluster (Karnataka)

Indian Institute of Science (IISc), National Centre for Biological Sciences (NCBS), Institute for Stem Cell Biology and Regenerative Medicine (inStem)

Focus Areas: Gene therapy, regenerative medicine, synthetic biology, bioinformatics

Companies: Biocon, AstraZeneca, Novozymes, Syngene

Incubators: Centre for Cellular and Molecular Platforms (C-CAMP), Bangalore Biotech Park

2. Hyderabad Biotech Cluster (Telangana)

Key Institutions: Centre for Cellular and Molecular Biology (CCMB), Indian Institute of Chemical Technology (IICT)

Focus Areas: Vaccines, diagnostics, agricultural biotechnology, gene therapy

Companies: Dr. Reddy's Laboratories, Aurobindo Pharma, Glenmark Pharmaceuticals, Serum Institute of India

Incubators: IKP Knowledge Park, CCMB-VenturEast Biotech Park

3. Delhi-NCR Biotech Cluster (National Capital Region)

Key Institutions: All India Institute of Medical Sciences (AIIMS), Indian Institute of Technology (IIT) Delhi

Focus Areas: Cancer research, infectious diseases, gene therapy, regenerative medicine

Companies: Panacea Biotec, Dabur Pharma, Fortis Healthcare, Max Healthcare

Incubators: Delhi Biotech Park, NCR Biotech Science Cluster

4. Mumbai-Pune Biotech Cluster (Maharashtra)

Key Institutions: Indian Institute of Technology (IIT) Bombay, University of Pune

Focus Areas: Biopharmaceuticals, bioinformatics, gene therapy, regenerative medicine

Companies: Cipla, Glenmark Pharmaceuticals, Piramal Healthcare, Serum Institute of India

Incubators: Mumbai Biotech Park, Pune Biotech Park

5. Chennai Biotech Cluster (Tamil Nadu)

Key Institutions: Indian Institute of Technology (IIT) Madras, University of Madras

Focus Areas: Biopharmaceuticals, bioinformatics, gene therapy, regenerative medicine

Companies: Orchid Pharma, Shasun Pharma, Strides Arcolab, Dr. Reddy's Laboratories

Incubators: Chennai Biotech Park, IIT Madras Research Park

6. Ahmedabad Biotech Cluster (Gujarat)

Key Institutions: Indian Institute of Technology (IIT) Gandhinagar, Gujarat University

Focus Areas: Agricultural biotechnology, gene therapy, regenerative medicine, bioinformatics

Companies: Cadila Healthcare, Torrent Pharmaceuticals, Zydus Cadila, Intas Pharmaceuticals

Incubators: Ahmedabad Biotech Park, Gujarat Biotechnology Venture Park

7. Pune Biotech Cluster (Maharashtra)

Location: Pune

Key Institutions: Indian Institute of Technology (IIT) Pune, University of Pune

Focus Areas: Biopharmaceuticals, bioinformatics, gene therapy, regenerative medicine

Companies: Serum Institute of India, Piramal Healthcare, Glenmark Pharmaceuticals, Cipla

Incubators: Pune Biotech Park, Venture Center

8. Coimbatore Biotech Cluster (Tamil Nadu)

Location: Coimbatore

Key Institutions: Tamil Nadu Agricultural University (TNAU), Coimbatore Institute of Technology (CIT)

Focus Areas: Agricultural biotechnology, bioinformatics, gene therapy

Companies: Shriram Group, Lakshmi Machine Works (LMW), KG Denim, Premier Mills

Incubators: Coimbatore Biotech Park, TNAU Incubation Center

Biotech Parks and their Roles in India -

1. Infrastructure Provision: State-of-the-art laboratories, equipment, and facilities.
2. Incubation and Acceleration: Supporting startups and early-stage companies.
3. Research and Development: Collaborating with academia, industry, and government.
4. Technology Transfer: Facilitating technology transfer from academia to industry.
5. Entrepreneurship Development: Encouraging entrepreneurship through training and funding.

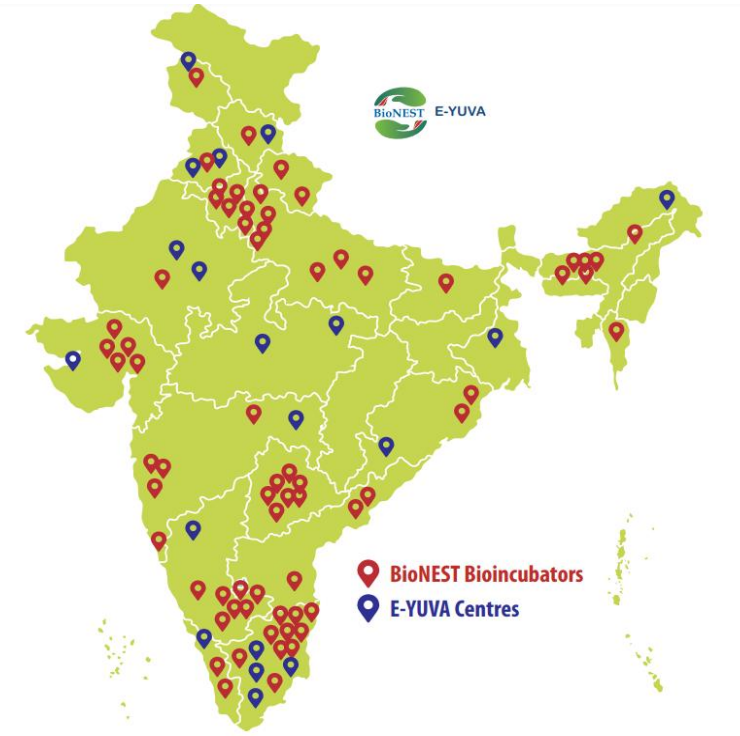
Biotechnology can play a crucial role in the development of rural and agriculture of India and also contribute in some other filed viz. Vaccines and diagnostics, Gene therapy and regenerative medicine, Agricultural biotechnology, Bioinformatics and computational biology, Synthetic biology, Cancer research, Infectious diseases, etc.

Agriculture and allied sector development of Biotech Cluster in India are – NABARD may collaborate with the Biotech Cluster for Precision agriculture, Agricultural diagnostics, etc.

Support from BIRAC: Biotechnology Industry Research Assistance Council (BIRAC) is a Schedule B 'Not-for-profit' Section 8, Public Sector Enterprise, set up by the Department of Biotechnology, Ministry of Science & Technology as an Interface Agency to strengthen and empower the emerging Biotech industry to undertake strategic research and Innovation, addressing nationally relevant product development needs. The mandate of BIRAC is to catalyse the transformation of the rapidly growing biotechnology sector in India including med-tech towards achieving excellence at global level. The Vision of the organisation clearly defines its core philosophy to create societal impact through cutting edge products that are affordable as well as exemplified in the statement 'affordable products addressing the needs of the largest

section of society'. This foundation has been built on the premise that for India to grow to become a knowledge driven economy it is essential that biotechnology plays a significant role in this endeavour. BIRAC aims to achieve the vision and mission, which have been enshrined in its charter, through various mechanisms that call for strategy involving multitudes of aligned partnerships such that bio-innovation takes root in start-ups, SMEs as well as in research institutes and academia. BIRAC operates through Public Private Partnerships (PPP) using various models: BIRAC's programs, schemes, and policy initiatives are supplemented through strategic collaborations, partnerships with National & International bodies, Government departments, Agencies, States, Industry, Angels/ VCs, Mentors, Experts, Philanthropic organizations, NGOs etc.

BIRAC's Bio-incubation (BioNEST) and pre-incubation (EYUVA) programmes have supported 95 bio-incubation facilities across the country. These facilities provide nurturing grounds for nascent ideas by providing access to highend infrastructure, specialized and advanced equipment, business mentorship, IP, legal and regulatory guidance, and networking opportunities. These facilities are located within Universities, Research Institutes, Research Hospitals, or as stand-alone centres. The centres have also been seeded in 21 States & 4 UTs, including Tier 2 & 3 cities bringing opportunities closer to the entrepreneurs, thereby obviating the need to dislocate from their home towns for the lack of opportunities locally. BioNEST & E-YUVA centres have supported more than 2500 incubatees & students, more than 1300 IPs have been filed by the incubatees, and 800+ products have reached market.



BIRAC's BIG programme has been instrumental in nurturing a pipeline of biotech startups. So far, more than 1000 innovative ideas have been supported out of 13,000+ applications received from across the country. The spread of aspirants covers 550+ cities and 38 aspirational districts pan India. More than 50% of the applications under BIG are from Tier 2&3 cities. Early-stage schemes like SITARE, Social Innovation Immersion Programme (SIIP), E-YUVA have been creating a pipeline of innovators for BIG scheme. Small Business Innovation Research Initiative (SBIRI) and Biotechnology Industry Partnership Programme (BIPP), the two flagship schemes of BIRAC support biotechnological product/technology

development by strengthening R&D capabilities of start-ups/companies/ LLPs. They provide the desired impetus for taking translational ideas forward for validation, scale-up, demonstration and pre-commercialization. SBIRI facilitates companies to take their Proof of Concept (PoC) towards early-stage validation. Since its inception in 2005, the scheme has supported 338 projects resulting in the validation/commercialization of 89 products/ technologies and filing of 52 patents. BIPP scheme serves as a launch pad for scaling and commercializing high-risk innovations through cost-sharing between BIRAC and the Industry. Since its inception, 249 projects including 69 collaborative projects have been supported under BIPP. A total of 103 products/technologies have been successfully developed and validated till date. While some of these have already been commercialized, others are at the pre-commercialization stage. The PACE Scheme (Promoting Academic Research Conversion to Enterprise) boosts translational research within academia. PACE has 2 components, namely AIR (Academic Innovation Research) which promotes the development of Proof-of-Concept (PoC) for a process/product by academia; and CRS (Contract Research Scheme) which enables validation of a process or prototype (developed by the academia) by an industry partner. So far, 169 projects have been supported under the scheme, with 10 technologies/ products validated and 26 IPs filed.

BIRAC Equity schemes constitute another major vertical of support for startups and biotech companies. SEED (Sustainable Entrepreneurship and Enterprise Development) Fund; LEAP (Launching Entrepreneurial Driven Affordable Products) Fund and Biotechnology Innovation (AcE-Accelerating Entrepreneurs) Fund-of-Funds, which offer support to the early-stage start-ups for differential growth, have helped the entities to attract private investment from Angels and VCs. By FY 2023-24, nearly 210 startups have been supported through equity support under SEED and LEAP. Out of these startups, more than 60% have raised follow-on funding amounting to about INR 856 Cr. There is a significant increase in the number of Startups getting investments from Angels, HNIs, and early-stage VCs, contributing to the growth story of the biotech industry. AcE-Fund-of-Funds has 14 daughter funds with BIRAC's investment commitment of INR 149.50 Cr. This has successfully mobilized INR 1172 Cr. investment in 88 biotech Companies. The AcE fund portfolio is being expanded by onboarding new daughter fund partners. BIRAC's in-house IP & Technology Management group (IPTEM) supports biotech innovators, start-ups, academia, and SMEs by providing expertise in patent searches, drafting, and filing, both domestically and internationally. The group also facilitates technology transfer, licensing, and commercialization to advance technology translation. To further enhance IP and Tech Transfer capabilities, the group regularly conducts sensitization workshops and webinars to increase knowledge and awareness.

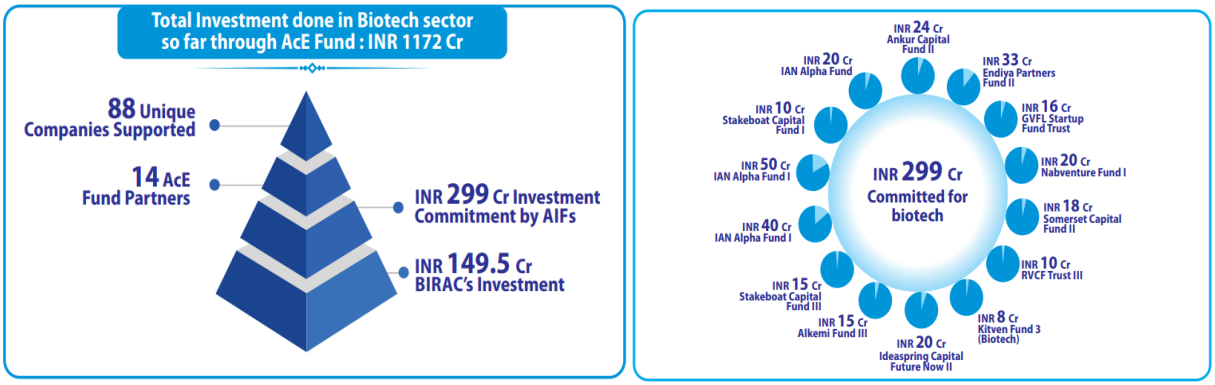
BIRAC's new initiative Regulatory Affairs and Policy Advocacy (RAPA) aims at strengthening the regulatory and policy milieu of India. The "Ask Me Anything" platform "FIRST HUB" is first of its kind single window facilitation platform to address the queries of

start-ups, entrepreneurs, researchers, academicians, incubation centres, SMEs etc. Till now, more than 850 queries have been addressed. BIRAC has been at the forefront of engaging with all stakeholders- the innovators, academia, Industry, SMEs, Investors, national and international partners and so on.

BIRAC spearheads regular national and international events that bring together stakeholders to showcase India's growing strength in the sector and create opportunities for connection, co-creation, co-development, and co-scaling. These events emphasize peer-to-peer learning, identifying gaps and opportunities, networking, and showcasing innovations.

The Make in India (MII) PMU of the Department of Biotechnology at BIRAC ensures wider dissemination of Government programmes and other information relevant to the establishment and growth of startups, SMEs, and large companies. MII PMU also contributes to the Start-up India action plan integrating BIRAC's facilitation for funding and incubation support to start-ups. It carries out annual mapping of India's Bioeconomy, facilitation of biotech innovation ecosystem, VCs, Angels & HNIs investors, Startups, and entrepreneurs onto the gamut of business-related issues in biotechnology such as regulatory landscape in the country, investment opportunities, FDI/ EXIM/ Industrial policies while working closely with Invest India and Startup India Cell at DPIIT and DBT. Policy-level inputs, leading new initiatives, and identifying and creating national and international opportunities for the biotech ecosystem are essential functions of the biotechnology Industry facilitation under Make In India facilitation PMU.

Notable outcomes of the Make in India initiatives led by BIRAC and DBT include Global Bio-India gaining international recognition as India's leading biotech business event, the abolishment of the angel tax, recalibration of customs duties for small-volume biotech reagents and standards, the invigoration of the NCR biotech cluster as India's first planned Bioscience Innovation Park, and the upscaling of the Fund of Funds – AcE to attract private equity and venture capital into the biotech ecosystem. There is a significant increase in the numbers of Startups raising private investments from VCs, Angels, and HNIs catalyzed by the Fund of Funds – AcE scheme. There are now 14 daughter funds with BIRAC's investment commitment of INR 149.5 Cr. It has successfully resulted mobilization



IMPACT OF AcE Fund

of INR 1172 Cr. investment in 88 biotech Companies so far. The AcE fund portfolio is being expanded by onboarding new daughter fund partners.

Bio-manufacturing and Bio-innovation are two key drivers identified for the growth of India's Bioeconomy and have been proposed in the BioE3 policy. Strategic reports, like the Annual India Bioeconomy Report (IBER) and the Biotech Showcase e-portal have become referral documents/repository for national and international stakeholders. The creation of Technology cluster as a national initiative recommended by MII cell through BIRAC, is expected to augment the capacity building under the Bio-Manufacturing initiative led by DBT/ BIRAC. The #BioE3 Policy is expected to give a new direction for the growth of future India that is powered with Jaïv Shakti.

An important element of BIRAC's strategy is facilitating technology transfer between academia and industry both within India and internationally.

Way forward: Bioeconomy has been recognized as a new chapter under the Brazilian G20 presidency to sensitize the world regarding a sustainable future using advances in biotechnology. India is one of the few countries already following up on the country's Bioeconomy year on year. The 13.6-fold growth in bioeconomy since 2013, with a notable acceleration seen between 2018 to 2023 has helped us to set an aspirational target of $300 billion USD by 2030. Bioeconomy's current contribution of 4% at $150.1 billion in 2023 is expected to increase to 10% of country's GDP by 2047. The BioE3 policy championed by DBT/ BIRAC is very timely. This is likely to bring focus on augmenting both Bio-manufacturing and Bio-innovation; and setting up biotech clusters in the country. Achieving India's BioEconomy growth to the $300 billion mark by 2030 would necessitate a focused and strategic use of current resources. This goal requires additional resource mobilization and effective integration with national and international stakeholders through Public-Private Partnership models. Furthermore, undertaking strategic tasks with clearly defined deliverables aligned with the overarching mandate will be crucial for success. As we progress, BIRAC would focus on consolidating its existing achievements and identifying key components that need further development. Priorities will include advancing Atmanirbhar Bharat, establishing India as a biomanufacturing hub, and transitioning from biosciences to bioeconomy.

Support for Biotech Startups - STARTUP INDIA

Status of Biotech startups in India: India is among the top 12 destinations for biotechnology worldwide. The Department of Biotechnology (DBT), under the Ministry of Science and Technology, has placed great emphasis on developing an ecosystem for the development of excellence and research in a variety of biotechnology fields in India. The number of biotech startup registrations has surged throughout the nation in 2021, with around 1,128 new startups registered, which is the highest in a single year since 2015. Estimates put the total number of biotechnology startups at 6,756 as of 2022. The number of startups is expected to reach 10,000 by 2025. India has 665 FDA-approved plants in the US; 44% of the global abbreviated new drug applications (ANDA) and more

than 1,400 manufacturing plants, which are compliant with WHO's requirements. The country is also the world's third-largest producer of recombinant Hepatitis B vaccine and second-largest producer of BT cotton (genetically modified pest-resistant plant cotton).

Support for Biotech Startups by BIRAC: Biotechnology Industry Research Assistance Council (BIRAC) is a not-for-profit Section 8, Schedule B, Public Sector Enterprise, set up by Department of Biotechnology (DBT), Government of India as an Interface Agency to strengthen and empower the emerging Biotech enterprise to undertake strategic research and innovation, addressing nationally relevant product development needs.

BIRAC's aim is to play a transformative and catalytic role in building a US$ 100 billion Indian bioeconomy. BIRAC's focus is particularly on biotech start-ups & SMEs, for creation of affordable products addressing the needs of the largest section of society

Support for Biotech Startups by Department of Biotechnology (DBT)

Biotech Park: The Department of Biotechnology promotes innovative research & development activities in biotech sector and also helps to translate research into products and services. The Biotechnology Parks, offer facilities to Scientists, and Small and Medium sized Enterprises (SMEs) for technology incubation, technology demonstration and pilot plant studies for accelerated commercial development of innovative leads. The overall objectives of Biotech Park scheme is to translate research outcomes into large scale manufacturing and product development and commercialization of biotechnologies by providing necessary infrastructure support to develop high quality basic infrastructure and high end central equipment facilities. This has helped in the promotion of commercial development of biotechnology within the country by setting up of research laboratories for product development, start-up companies and small and medium enterprises. The Department has so far supported 12 biotechnology parks at various States for accelerating the commercialization of new technologies, nurturing and maintaining emerging ventures and assisting new enterprises to forge appropriate linkages with other stakeholders. These are: i) Biotech Park, Lucknow, Uttar Pradesh; ii) Biotechnology Incubation Centre, Hyderabad, Telangana; iii) Tidco Centre For Life Sciences (TICEL) Biotech Park, Chennai, Tamil Nadu; iv) The Golden Jubilee Biotech Park For Women, Chennai, Tamil Nadu; v) Biotech Park Technology Incubation Centre, Guwahati, Assam; vi) Biotechnology Incubation Centre, Cochin, Kerala; vii) Biotechnology Park, Bangalore, Karnataka; viii) Two (02) Industrial Biotechnology Parks (IBTPs), Jammu & Kashmir; ix) Chhattisgarh Biotech Park, Naya Raipur, Chhattisgarh and (x) Biopharma Growth Phase park, and a common Scale up manufacturing facility with training provision in Genome valley, Hyderabad. These Biotech parks are successfully accelerating the commercialization of new technologies, nurturing and maintaining emerging ventures and assisting new enterprises to forge appropriate linkages with other stakeholder of biotechnology sector including academia and Government. Recently, DBT has approved a project

for Setting up a Madhya Pradesh Biotechnology Park, at village 'Cheerakhan', Tehsil Pithampur in Indore. This Biotech Park would be a robust platform which would support the agri-entrepreneurs, Startups, Progressive farmers, young entrepreneurs, scientists, scholars and students not only from Madhya Pradesh but also from nearby States. This will also provide the opportunity to develop a culture for promoting plant tissue culture industries to enhance the farmer's income. The proposed Biotech will be the first of its kind in the Central India with a cluster of Life sciences industry, research Institutions, sci-tech academia and other scientific amenities. The Department has come up with 'National Biotechnology Parks Scheme' in which it is proposed to create an ecosystem to absorb the start-ups graduated from the incubators and give them a platform for further scaling up their R&D activities in collaboration with the state government and industry.

'Bio-RIDE' scheme to support cutting edge research and development in Biotechnology: The Union Cabinet, chaired by the Prime Minister Shri Narendra Modi, approved on 18 Sep 2024 continuation of the two umbrella schemes (Biotechnology Research and Development and Industrial & Entrepreneurship Development (I&ED)) of Department of Biotechnology (DBT), merged as one scheme 'Biotechnology Research Innovation and Entrepreneurship Development (Bio- RIDE)' with a new component namely Biomanufacturing and Biofoundry. Bio-RIDE is a merger of Biotechnology Research and Development and Industrial & Entrepreneurship Development (I&ED) of Department of Biotechnology with a new component i.e. Biomanufacturing and Biofoundry. The scheme has three broad components:

- Biotechnology Research and Development (R&D)
- Industrial & Entrepreneurship Development (I&ED)
- Biomanufacturing and Biofoundry

The proposed outlay for the implementation of the unified scheme 'Bio-RIDE' is ₹9197 crore during the 15 finance Commission period from 2021-22 to 2025-26. The DBT's ongoing efforts align with its vision of harnessing the potential of Biotechnology as a precision tool for national development and well-being of society to fulfil its mission to make India globally competitive in Biotechnology research, innovation, translation, entrepreneurship, and industrial growth and be a US$300 billion Bioeconomy by 2030. The Bio-RIDE Scheme will contribute significantly towards realizing the vision of 'Viksit Bharat 2047'. The scheme is part of the Government of India's mission to harness the potential of bio-innovation to tackle national and global challenges such as healthcare, agriculture, environmental sustainability, and clean energy. Implementation of Bio-RIDE Scheme will:

i. **Promote Bio-Entrepreneurship:** Bio-RIDE will nurture a thriving ecosystem for startups by providing seed funding, incubation support, and mentorship to bio-entrepreneurs.

ii. **Advance Innovation:** The scheme will offer grants and incentives for cutting-edge research and development in areas like synthetic

biology, biopharmaceuticals, bioenergy, and bioplastics.

iii. **Facilitate Industry-Academia Collaboration:** Bio-RIDE will create synergies between academic institutions, research organizations, and industry to accelerate the commercialization of bio-based products and technologies.

iv. **Encourage Sustainable Biomanufacturing:** A significant focus will be placed on promoting environmentally sustainable practices in biomanufacturing, aligned with India's green goals.

v. **Support researchers through Extramural funding:** Bio-RIDE will play critical role in advancing scientific research, innovation, and technological development across diverse fields of biotechnology by supporting extramural funding to research institutions, universities, and individual researchers in areas such as agriculture, healthcare, bioenergy, and environmental sustainability.

vi. **Nurturing Human Resource in Biotechnology sector:** Bio-RIDE will provide holistic development and support to students, young researchers and scientists working in the multidisciplinary areas of Biotechnology. The integrated programme of Human Resource Development will contribute towards the capacity building and skilling of the manpower and make them competent to leverage the newer horizon of technological advancements.

Funding Opportunities in the Biotech Ecosystem -Equity Support to Startups from DBT-BIRAC: The Department of Biotechnology (DBT) and the Biotechnology Industry Research Assistance Council (BIRAC) in India actively support and promote biotech startups through various funding opportunities. DBT and BIRAC are key players in driving the growth of the biotech ecosystem in India. Their funding opportunities have been instrumental in supporting and nurturing innovation in the field. By providing grants, fellowships, and investments, DBT and BIRAC have helped researchers, startups, and institutions translate their ideas into impactful biotech products and solutions. The equity schemes/funds offered by BIRAC to support biotech startups:

S. No.	Equity schemes/funds	Particulars
1	SEED fund (Sustainable Entrepreneurship and Enterprise Development)	• Equity exposure: Up to INR 30 lakhs • Purpose: Capital assistance for post PoC startups with new and meritorious ideas, innovations, and technologies. • Implementation: Implemented through selected BioNEST Incubators, who receive grant-in-aid support of INR 200 lakhs/cycle. • Impact: 112 startups supported with equity investment of INR 30 crore. Around 118 products have been commercialized by beneficiary startups.
2	LEAP FUND (Launching Entrepreneurial driven Affordable Products Fund)	• Equity exposure: Variable • Purpose: Assists potential startups in piloting and commercializing their products and technologies, enabling them to raise venture capital investment. • Implementation: Implemented through selected BioNEST Incubators, who receive grant-in-aid support of INR 500 lakhs/cycle. • Impact: 47 startups supported with equity investment of INR 30 crore. Around 46 products have been commercialized by beneficiary startups.
3	BioAngels Program	• Purpose: Partnership between BIRAC and IAN (Indian Angel Network) to support startups in various sectors, including biotech, medtech, healthtech, pharma, agritech, and cleantech. • Implementation: Involves interactions with high-quality investors and industry leaders, providing money, mentoring, and market access.
4	“Fund of Funds - AcE”- (Accelerating Entrepreneurs)	• Purpose: Foster R&D and innovation by encouraging VC investment for biotech startups and SMEs through AIFs (Alternative Investment Funds) daughter funds. • Fund Corpus BIRAC/DBT: INR 150 Cr • Implementation: Partners with SEBI-registered Category I and II AIFs, which invest in biotech startups and SMEs. • Impact: INR 733 crore investment in biotech startups, with around 65 startups being supported.

Biotech-Kisan Hubs: Hubs established in all 15 agro-climatic zones and through 55 interventionsintroduced to benefit farming community, >3 lakh farmers have been benefited (https://dbtindia.gov.in/sites/default/files/DBT%20coffee%20table%20book.pdf)

Biotech-Krishi Innovation Science Application Network (Biotech-KISAN):The Biotech-Krishi Innovation Science Application Network (Biotech-KISAN) is a government initiative launched in 2017 under the Department of Biotechnology, Ministry of Science and Technology, India. The programme is designed to facilitate farmer-scientist collaborations to address region-specific agricultural challenges through the application of biotechnology. It aims to foster innovation, empower small and marginal farmers, particularly women, and improve agricultural productivity by linking science and technology directly to the farm. The programme operates through a hub-and-spoke model across India's 15 Agro-climatic zones and aspirational districts, ensuring that scientific interventions reach the grassroots level. The Biotech-KISAN scheme focuses on understanding the specific challenges faced by local farmers and scouting for appropriate technologies to address issues related to water, soil, seed, and market access. It implements demonstration and scale-up programmes to provide practical solutions to these problems while creating a strong platform for interaction between scientists and farmers. Through this platform, farmers receive training, and scientists participate in immersion programmes to deepen their understanding of farming needs. The scheme also ensures effective communication with farmers via radio, TV, and social media. It offers individual thematic fellowships, allowing selected farmers to gain hands-on experience in high-tech science laboratories. Further, special solution-driven fellowships, known as Mahila Kisan Biotech Fellowships, are provided to women farmers, empowering them to become grassroots leaders and innovators in the agricultural sector. The Biotech-KISAN programme comprises several key components aimed at enhancing agricultural productivity and innovation. First, the Biotech-KISAN Hubs serve as central units in each of the 15 Agro-climatic zones, connecting farmers with scientific institutions and providing technical support and resources for solving local agricultural challenges. Each hub is financially supported and acts as a facilitator of innovation and knowledge transfer. Second, Partner Institutions, including Krishi Vigyan Kendras (KVKs) and agricultural universities, collaborate with the hubs to conduct training programmes and demonstrations, focusing on improving seed quality, bio-fertilizer usage, and innovative livestock management. These institutions receive funding for their contributions to specific activities. Third, Research Projects are an essential component, allowing scientists to propose solutions for larger, identified challenges with the potential for additional funding based on their research scope. Further, International Training programmes expose farmers and scientists to global agricultural best practices, strengthening the programme's ability to incorporate advanced technologies and methodologies into Indian agriculture. As of 2023, the Biotech-

KISAN programme has made notable progress in enhancing agricultural outcomes for small and marginal farmers. With the establishment of 52 Biotech-KISAN Hubs across 15 Agro-climatic zones, covering over 115 aspirational districts, the programme has directly and indirectly benefited over 300,000 farmers. These hubs have provided access to improved farming techniques and better market opportunities, while the programme has also fostered the development of more than 200 rural entrepreneurs. Through its support for Farmer Producer Organizations (FPOs) and Self-Help Groups (SHGs), Biotech-KISAN has strengthened marketing linkages for farmers, ultimately boosting their profitability. The programme's success stories highlight the effectiveness of its farmer-scientist partnership model. In Bihar, farmers revived grass pea cultivation with scientific support, resulting in increased agricultural productivity and income. In the Sundarbans of West Bengal, women farmers adopted scientific goat and sheep rearing practices, improving livestock management and household income. Similarly, in North Coastal Andhra Pradesh, farmers enhanced pulse production by utilizing rice fallows, guided by scientific interventions from local Biotech-KISAN Hubs. These examples underscore the programme's impact on rural communities through tailored scientific solutions and innovative agricultural practices.

As part of its mission, the Department of Biotechnology (DBT) has issued a Special Call for the Northeast Region (NER) under the Biotech-KISAN programme. This call aims to understand the local agricultural problems in NER and provide scientific solutions. The NER, which is predominantly agrarian, with 70% of its workforce engaged in agriculture and allied sectors, presents a unique set of challenges and opportunities. Despite its rich potential, the region produces only 1.5% of the country's food grain and remains a net importer of food for domestic consumption. The programme seeks to enhance the income of farmers by promoting location-specific crops, horticulture, fisheries, and livestock production. To address the specific needs of NER, Biotech-KISAN will focus on linking innovative agricultural technologies with small and marginal farmers, especially women, in the region. The hubs established in NER will collaborate with top scientific institutions, State Agricultural Universities (SAUs), KVKs, and existing state agriculture extension services to demonstrate technologies and provide training to farmers. This localized approach is expected to significantly enhance agricultural productivity and the livelihoods of farmers in NER. The Biotech-KISAN scheme represents a significant step forward in the integration of biotechnology with Indian agriculture. By fostering collaboration between farmers and scientists, the programme addresses critical challenges in agriculture, promotes sustainable practices, and empowers marginalized communities. With its continued expansion and focus on empowering women farmers, Biotech-KISAN is poised to further contribute to

the transformation of India's agricultural landscape.

(https://dbtindia.gov.in/sites/default/files/Biotech-KISAN-Scheme-1.pdf

https://dbtindia.gov.in/sites/default/files/Special%20Call%20Of%20Biotech%20KISAN%20for%20the%20North%20East%20Region%20of%20India.pdf (North Eastern Region)

https://dbtindia.gov.in/biotech-kisan#

https://vikaspedia.in/agriculture/policies-and-schemes/crops-related/biotech-kisan-scheme

https://pib.gov.in/PressReleasePage.aspx?PRID=1728507)

04 Regulatory Framework

Regulations and Guidelines on Biosafety of Recombinant DNA Research & Biocontainment, 2017:

The Regulations and Guidelines on Biosafety of Recombinant DNA Research & Biocontainment, 2017 in India outline a comprehensive framework for ensuring safe and responsible conduct of recombinant DNA research. These regulations are crucial to safeguarding public health, environmental safety, and the overall well-being of society. The Guidelines cover the regulations on biosafety of rDNA research and handling of hazardous microorganisms and GE organisms or cells in India. It has described stringent and robust facility structures for handling microorganisms, animals, plants, insects and aquatic organisms and has provided clear instruction on disposal and decontamination of laboratory wastes, emergency procedures etc. The guidelines include a list of risk group agents and determined appropriate containment level for their handling in India. The key provisions of the Regulations are:

- **Biosafety Levels:** The regulations establish four biosafety levels (BSL-1 to BSL-4) based on the potential risk posed by the research. Each level specifies containment requirements, personal protective equipment, and laboratory practices to minimize the risk of exposure to hazardous biological agents.
- **Institutional Biosafety Committee (IBC):** The regulations require the establishment of an IBC at each institution conducting recombinant DNA research. The IBC is responsible for reviewing and approving research proposals, ensuring adherence to biosafety guidelines, and monitoring laboratory practices.
- **Risk Assessment:** Before initiating any recombinant DNA research, a thorough risk assessment must be conducted to evaluate the potential risks associated with the research and determine the appropriate biosafety level. Factors considered in risk assessment include the nature of the organism, the genes being manipulated, and the potential for accidental release or spread.
- **Biocontainment Facilities:** The regulations specify requirements for biocontainment facilities, including

physical containment measures (e.g., sealed doors, ventilation systems), personal protective equipment, and emergency procedures. The level of biocontainment must correspond to the biosafety level of the research.

- **Import and Export of GMOs:** The regulations govern the import and export of GMOs, ensuring that appropriate permits and documentation are in place to prevent the introduction of harmful organisms.
- **Public Awareness and Education:** The regulations emphasize the importance of public awareness and education regarding recombinant DNA research. The government and institutions are encouraged to disseminate information about the benefits and risks of this technology to promote public understanding and acceptance.
- **Enforcement and Penalties:** The regulations outline enforcement mechanisms and penalties for non-compliance. This ensures that institutions and researchers adhere to the guidelines and maintain a high level of biosafety.

Scope of Regulation: These regulations are to implement the provisions of Rules 1989 of Environment (Protection) Act, 1986 for the manufacture, use, import, export and storage of hazardous microorganisms, GE organisms or cells and products thereof which applies to the whole of India in the following specific cases:

- Sale offers for sale, storage for the purpose of sale, offers and any kind of handling over with or without consideration.
- Exportation and importation.
- Production, manufacturing, processing, storage, import, drawing off, packaging and repacking of the GE Products.
- Production, manufacture etc. of drugs and pharmaceuticals, food and food

Mandate of Ministries/ Departments:

Ministry	Mandate of Ministries/ departments
Ministry of Environment, Forest and Climate Change	• Primarily responsible for conservation and protection of environment ensuring environmental & human health safety before release of GMOs/LMOs • Nodal agency for implementing rules, 1989 and the Cartagena protocol on Biosafety
Department of Biotechnology (Ministry of Science and Technology)	• Nodal department for promoting biotechnology programs • Provides scientific support in implementation of biosafety regulations.
Ministry of Agriculture	• Policies aimed at agriculture growth • Indian Council of Agricultural research (ICAR) responsible for monitoring agronomic benefits of GM technology. • Monitoring post release performance of GM crops.
Ministry of Health and family Welfare	• Policies aimed at protecting and monitoring human health. • Food safety and Standards Authority of India responsible for regulating genetically engineered foods.
Ministry of Commerce and Industries	• Enhance trade with other countries through export/ import policies • Nodal agency for implementing DGFT notification on GMOs
Central board of Excise and Customs, Department of Revenue, Ministry of Finance	• Enforcement of regulation pertaining to transboundary movements of GMOs/ LMOs at point of entry.

components, distilleries and tanneries, etc. which make use of hazardous micro-organisms or GE organisms one way or the other

Additional regulations/guidelines for Biotechnology industries: The Biotechnology industry in India is governed by the following enactments depending upon their relevance/ applicability on case-to-case basis.

- The Environment (Protection Act) 1986
- Foreign Exchange Management Act, 1999
- Rules for the Manufacture, Use/ Import/Export and Storage of Hazardous Micro Organisms/ Genetically Engineered Organisms or Cells, 1989
- Revised Recombinant DNA Safety Guidelines- 2017
- Revised Guidelines for Research in Transgenic Plants, 1998
- Guidelines for the safety assessment of foods derived from Genetically Engineered Plants, 2008
- Guidelines for the monitoring of

confined field trials of regulated genetically engineered Plants, 2008

- Seeds Act, 1966
- The Plants, Fruits and Seeds [Regulation of import in India] Order 1989 issued under the Destructive Insects and Pests Act, 1914.
- Drugs and Cosmetics (Amendment) Act, 2008
- Guidelines for Generating Pre-Clinical and Clinical Data for r-DNA Based Vaccines, Diagnostics and other Biologicals, 1999.
- Bio-medical Waste Management Rules, 2016.
- Biological Diversity Act, 2002.
- Disaster Management Act, 2005.
- Food Safety and Standards Act, 2006.
- Hazardous Waste Management Rules, 2016.
- Industries (Development & Regulation) Act, 1951 - New Industrial Policy & Procedures, 1991.
- Plant Quarantine (Regulation of Import into India) Order, 2003.
- Protection of Plant Var. and Farmers' Rights Act 2001, PPV & FR Regulations 2006.

Other applicable Policies

- EXIM Policy
- National Seed Policy, 2002
- Pharmaceutical Policy, 2002
- Risk analysis Framework, 2016
- Laws pertaining to Intellectual Property Rights
- Import policy of Genetically Modified Food, Feed, Genetically Modified Organism (GMOs) and Living Modified Organisms (LMOs) notified by Directorate General of Foreign Trade

05 SWOT Analysis of Biotechnology in India

Strengths

Biotechnology industry in India has contributed significantly to the BioEconomy and the global acceptance of biosimilar products are driving an expected growth to nearly US$ 63 billion by 2025, indicating a promising trajectory. Some the strength areas of the Biotechnology industry in India have been given as under:

i) Skilled human capital

a. India has a large reservoir of scientific human resources including scientists and engineers. With a total population of 1.4 billion, 47% being under the age of 25, India has a large pool of young and skilled workforce.

b. Biotechnology has emerged as a trending career option among the youth. According to a survey of Class 12th students in Delhi, Biotechnology was ranked as the preferred stream at No.4/5.

ii) Government Support

a. There are 12 DBT-supported Biotech Parks and 75 BIRAC-supported bio-incubators.

b. National Biopharma Mission is supporting 101 projects including more than 150 organizations and 30 MSMEs.

c. The National Biotechnology Development Strategy 2020-25, provides the government with a platform to strengthen skill development, resource and innovation converging into one strong ecosystem for knowledge sharing

iii) FDI Policy

a. 100% under automatic route for greenfield projects for pharmaceuticals.

b. While 74% is permitted under automatic route for brownfield projects, 100% under government route is permitted for brownfield investments.

c. 100% under automatic route is allowed for the manufacturing of medical devices.

iv) Epidemiological factors

a. a) Patient pool expected to increase over 20% in the next 10 years, mainly due to rise in population.

b. b) New diseases & lifestyle changes to boost demand for drugs and devices.

v) Global collaboration, Technological challenges and innovation:

India has developed good strategic international cooperation which is essential for the exchange of knowledge, experience, and technology transfer in biotechnology, which will help develop collaborative ways to address global challenges such as combating infectious diseases (e.g. Covid -19 i.e. SARS-CoV-2) and achieving sustainable development.

Weakness

The use of modern biotechnology, while goals of food security are clearly articulated and agreed at the international level, goals of nature protection, environmental safety and sustainable agriculture are much more complex, unclear and vary depending on the features of a particular region. Some of the issues of using biotechnology in

India, given below may be considered as weaknesses of the sector:

i) Ethical challenges: Modern biotechnology requires deeper discussion/platforms, and the development of ethical standards to balance scientific progress with protecting society from the negative consequences associated with biotechnological innovation and influence public perception. The principle of "Traceability" in the chain of fodder and food production, has not been strictly implemented in India There should be integrated perspective and approach to agricultural technologies to ensure that ethical assessments of the effects of new technology considering production, storage and distribution.

ii) Sociocultural challenges: Growth of unfair distribution of income of a certain producer of agricultural products and an owner of patents for modern biotechnology. The farmers' income growth still remains uncertain and subject to climate risks.

iii) Safety and environmental concern: The use of biotechnology can have unpredictable environmental consequences. The use of GMOs, despite wide and rapid spread, is a concern. Uncontrolled transfer of GMO structures, especially those determining different types of resistance to pesticides, pests and plant diseases, due to over pollination with wild related and ancestral species. In this regard, reduction of biodiversity of wild ancestral forms of cultivated plants and formation of "super weeds" is more. This could be an impact on biodiversity through affection of non-target insects and soil microflora with toxic transgenic proteins as well as violation of trophic chains.

iv) Loss of genetic diversity among native species: The use of biotechnology-derived seeds could lead to a loss of genetic diversity among crops, as native species can be replaced in the same way that modern hybrids have replaced many traditional varieties or breeds. Moving towards genetic homogeneity can lead to a greater susceptibility of plants to many pests, diseases or other negative environmental impacts, problems that are the scourge of monoculture agriculture.

v) Lack of classification of risks for agriculture GMO products for clear understanding by common public. The fear of GMOs arises because of poor public awareness. There should be proper and clear classification of risks i.e. the level of possible harm and safety for key components of the food market: food products, environment, agriculture, consumer health, etc. This classification of risks can be used to develop measures to prevent the impact of possible threats from the introduction of GMOs in agriculture.

vi) Regulation and legislation: Existing legislation is not always in line with the rapid development of biotechnology. There is a need to develop an appropriate legal framework to balance innovation and to ensure the safety and efficient management of biotechnological processes.

Opportunities

In India, biotechnology in agriculture holds significant potential due to the country's growing population, agricultural dependence, and the need to enhance food security, sustainability, and resilience to climate change. The

Indian government, research institutions, and private sector are increasingly focused on leveraging biotechnology to improve crop yields, pest resistance, and environmental sustainability. Here are key opportunities for biotechnology in Indian agriculture:

1. Crop Improvement through Genetic Engineering

- **Genetically Modified (GM) Crops:** India has already adopted Bt cotton, a genetically modified (GM) crop resistant to pests, which has led to a significant increase in cotton yield. There are opportunities for expanding GM crops to other major crops like rice, maize, and wheat to improve yields, resistance to pests, and environmental stress (drought, salinity, etc.).
- **CRISPR and Gene Editing:** India is exploring gene editing technologies like CRISPR to develop crops that are more resilient to climate conditions, have better nutritional content, and require fewer resources.

2. Biopesticides and Biofertilizers

- **Biopesticides:** The demand for eco-friendly, sustainable agriculture solutions is rising in India, driven by concerns over the environmental and health impacts of chemical pesticides. Biotechnology can be used to develop natural biopesticides derived from microorganisms or plants, reducing dependency on chemical inputs.
- **Biofertilizers:** Using microbes such as nitrogen-fixing bacteria to enhance soil fertility is another promising area. Companies and research institutions are working on biotechnology-based biofertilizers that improve nutrient uptake by plants, reduce chemical fertilizer use, and increase soil health.

3. Sustainable Agriculture and Climate-Resilient Crops

- **Drought and Flood-Resistant Crops:** Climate change has a significant impact on Indian agriculture, with increasing incidences of droughts, floods, and extreme weather events. Biotechnology can help develop climate-resilient crops that can withstand such stress, ensuring food security in changing environmental conditions.
- **Salt-Tolerant Crops:** In coastal regions and areas affected by soil salinity, there is a growing demand for salt-tolerant crop varieties. Biotechnology offers solutions by developing crops that can thrive in saline soils.

4. Precision Agriculture

- **Genomics and Marker-Assisted Breeding:** Using biotechnology tools such as molecular markers, Indian researchers and companies can identify genes responsible for desirable traits (yield, disease resistance, drought tolerance) and use marker-assisted selection to breed superior crop varieties more efficiently.
- **Genomic Data and AI:** Combining biotechnology with AI and data analytics can provide farmers with personalized farming solutions based on soil, weather, and crop genomic data. This approach helps optimize input use and improve yields.

5. Improving Nutritional Quality (Biofortification)

- **Biofortified Crops:** Biotechnology can play a critical role in combating malnutrition in India by biofortifying staple crops such as rice, wheat, and maize with essential vitamins and minerals (e.g., Vitamin A, iron, and zinc). This can address widespread deficiencies and improve public health outcomes.
- **Golden Rice:** Biofortified with Vitamin A, Golden Rice is a notable example. The promotion of similar biofortified crops in India could improve nutritional security.

6. Seed Biotechnology

- **Hybrid Seed Development:** India has a growing market for hybrid seeds that offer higher productivity. Biotechnology can accelerate the development of high-yield, disease-resistant hybrid varieties, improving farmers' incomes.
- **Seed Treatment and Coating:** Biotechnology is being used to enhance seed treatment technologies, including coatings with beneficial microorganisms that improve germination rates, plant health, and resistance to pests.

7. Biotechnology in Horticulture and Floriculture

- **Tissue Culture:** Tissue culture techniques are widely used in India for rapid propagation of disease-free, high-quality plants, especially in horticultural crops like bananas, sugarcane, and ornamental plants. This allows for large-scale production and improved yield.
- **Genetic Engineering for Value Addition:** Biotechnology can help develop improved horticultural varieties with extended shelf life, better taste, and disease resistance, which is vital for both domestic and export markets.

8. Biotechnology for Livestock and Aquaculture

- **Animal Biotechnology:** Advances in genomics and biotechnology offer opportunities for improving livestock breeding, health, and productivity. Genetic improvements can result in better dairy and meat yields, while disease resistance can help reduce losses.
- **Aquaculture:** India's aquaculture sector can benefit from biotechnology by developing disease-resistant and fast-growing fish species, ensuring sustainable fish production. Biotechnology can also help improve feed quality and reduce environmental impacts in aquaculture practices.

9. Post-Harvest Biotechnology

- **Biotech Solutions for Reducing Post-Harvest Losses:** Biotechnology offers methods for extending the shelf life of perishable crops and reducing losses during storage and transportation. Developing crops with better resistance to spoilage can reduce waste and improve food security.
- **Enzyme Technology:** Biotechnology can enhance food processing industries by developing enzymes that aid in processing agricultural products more efficiently, enhancing both productivity and product quality.

10. Research and Development (R&D)

- **Collaborative Research:** India is home to several agricultural research institutions, such as the Indian Council of Agricultural Research (ICAR), that collaborate with international biotech companies and universities. There are ample opportunities for professionals in R&D to contribute to advancements in agricultural biotechnology.
- **Public-Private Partnerships:** The Indian government encourages partnerships between biotech companies, research institutions, and farmers to promote the development and adoption of biotech innovations.

11. Government Initiatives and Public Support

- **Government Schemes:** India's government supports biotechnology in agriculture through schemes like the National Biopharma Mission, Biotechnology Industry Research Assistance Council (BIRAC), and National Mission on Agricultural Extension and Technology. These programs provide funding, infrastructure, and regulatory support for the development of biotech products.
- **Ease of Regulatory Approvals:** The Indian government is working on simplifying regulatory frameworks for biotechnology, including genetically modified crops. If regulations become more streamlined, it will create more opportunities for biotech companies to introduce innovative products in the market.

12. Biotech Startups and Entrepreneurship

- **Agri-Biotech Startups:** India has a growing number of agri-biotech startups focusing on innovations like biofertilizers, biopesticides, soil health improvement, precision agriculture tools, and smart farming solutions. These startups are increasingly receiving venture capital funding and government support, creating an ecosystem of innovation in agricultural biotechnology.
- **Incubators and Accelerators:** India's growing network of biotech incubators and accelerators offers mentorship, funding, and commercialization support for agri-biotech startups.

Biotechnology in Indian agriculture presents significant opportunities across crop improvement, sustainability, precision farming, biofertilization, livestock management. With growing government support, a large agricultural base, and increasing private sector participation, the sector is poised for transformative growth. Entrepreneurs, scientists, and agritech professionals can leverage these opportunities to create impactful solutions for Indian agriculture.

Threats

While biotechnology offers vast potential for transforming sectors like agriculture, healthcare, and industry in India, it also faces significant threats and challenges that could hinder its growth and adoption. Here are the key threats to biotechnology in India:

1. Regula tory Hurdles and Delays

- **Bureaucratic Delays:** India's regulatory approval process for

biotech products, especially genetically modified (GM) crops, can be slow and cumbersome. Lengthy approvals and bureaucratic red tape create significant delays in bringing new biotech innovations to market, which discourages investment and innovation.

- **Regulatory Uncertainty:** Changing regulations and a lack of clear guidelines for the commercialization of biotechnologies, including gene editing and synthetic biology, create uncertainty for companies and researchers. This can lead to reluctance from investors and slow down the adoption of emerging technologies.
- **Public and Political Opposition to GM Crops:** There has been strong political and social resistance to genetically modified crops in India, particularly in the case of food crops. Activist groups and political parties have raised concerns over potential health risks, environmental impacts, and corporate control over seeds, leading to bans or restrictions on some GM crops.

2. Public Perception and Ethical Concerns

- **Misinformation and Fear:** Public fear and misconceptions about biotechnology, especially GMOs, gene editing, and synthetic biology, can lead to a lack of acceptance and widespread adoption. Misinformation about the safety of GM crops, vaccines, and biotechnological innovations can cause public resistance, stalling progress.
- **Ethical and Cultural Concerns:** Biotechnology-related issues, such as genetic modification, cloning, and stem cell research, can raise ethical questions and conflicts with cultural and religious values. This can impact public perception, political decisions, and the willingness to adopt certain biotech solutions.
- **Food Security vs. Biotech Risks:** While biotechnology offers solutions for improving food security, concerns remain that reliance on GM seeds and biotech solutions could create new dependencies on multinational corporations or reduce biodiversity.

3. Limited Infrastructure and Funding for R&D

- **Inadequate Research Infrastructure:** While India has made strides in biotechnology, many research institutions lack the advanced infrastructure needed for cutting-edge biotechnological research. This includes inadequate laboratories, equipment, and access to modern technologies like CRISPR or bioinformatics platforms.
- **Insufficient Funding:** Although the Indian government and private sector are investing in biotechnology, the level of funding is still not on par with global standards. The biotech sector, especially startups, often struggles with access to venture capital, research grants, and financial resources to scale their innovations.
- **Brain Drain:** The lack of world-class research facilities and funding opportunities in India often leads to a "brain drain," where talented scientists and biotech professionals leave the country to pursue

opportunities abroad, affecting local innovation and research capacity.

4. Intellectual Property (IP) and Legal Challenges

- **Weak Intellectual Property Protection:** While India has made progress in IP laws, enforcement remains a challenge. Companies working on biotech innovations face risks of patent infringement and a lack of robust legal protections. This discourages both domestic and foreign investment in biotech R&D.
- **High Costs of Patent Filing:** Obtaining patents for biotech innovations can be costly and time-consuming in India, especially for startups or academic researchers. This hinders the commercialization of new discoveries and products.
- **Patent Disputes:** The field of biotechnology, especially in areas like genetic modification and pharmaceuticals, is prone to patent disputes. Legal battles over IP rights can slow down research and commercialization efforts.

5. Environmental and Ecological Risks

- **Unintended Environmental Consequences:** There is concern that certain biotechnology applications, particularly genetically modified organisms (GMOs), could have unintended environmental consequences. For example, GM crops could potentially cross-breed with wild species, leading to ecological imbalances.
- **Loss of Biodiversity:** The widespread adoption of GM crops could lead to monocultures, where a few genetically similar crops dominate agriculture, potentially leading to a reduction in biodiversity. This makes ecosystems more vulnerable to diseases or environmental changes.
- **Resistance Development:** Pests and weeds could develop resistance to biotech solutions like Bt crops (insect-resistant crops), leading to the emergence of "super pests" or herbicide-resistant weeds, which could harm the environment and agricultural productivity in the long term.

6. Economic Inequality and Farmer Dependence

- **Farmer Dependency on Biotech Corporations:** There is a concern that the widespread adoption of biotech seeds could make small-scale farmers dependent on large biotech corporations for seeds and inputs. This could increase the costs for farmers, limit seed diversity, and reduce traditional farming practices, especially in rural areas.
- **High Cost of Biotech Products:** Advanced biotech solutions, such as genetically modified seeds, biofertilizers, biopesticides, can be expensive, putting them out of reach for small and marginal farmers in India. This could lead to increased inequality in agriculture, with only larger, wealthier farmers benefiting from biotech innovations.

7. Lack of Skilled Workforce

- **Shortage of Biotech Professionals:** There is a growing demand for skilled professionals in biotechnology, including molecular

biologists, bioinformaticians, biochemists, and data scientists. However, India's education and training infrastructure is not yet equipped to produce enough skilled workers to meet this demand.

- **Skill Mismatch:** Even when there is a workforce, the gap between academia and industry in terms of skill requirements is significant. Many graduates in biotechnology lack the practical skills and industry-relevant knowledge to contribute effectively in a fast-evolving biotech sector.

8. Global Competition

- **Foreign Competition:** Indian biotech companies face strong competition from global players, especially in areas like biopharmaceuticals and agricultural biotechnology. Developed countries often have better infrastructure, funding, and regulatory frameworks that allow them to move faster and dominate global biotech markets.
- **Trade Barriers:** Regulatory barriers, trade restrictions, and differing standards in biotechnology products across countries can affect India's ability to compete in the global market, especially when exporting GM crops or biotech-based products.

9. Lack of Awareness and Adoption by Farmers

- **Farmer Education and Awareness:** One of the key challenges in the adoption of biotech solutions, particularly in agriculture, is the lack of awareness and understanding among farmers about the benefits and risks of biotechnology. Without adequate education, many farmers are hesitant to adopt new technologies or fall prey to misinformation.
- **Access to Biotech Solutions:** Rural farmers in India often lack access to biotechnology innovations due to infrastructure, financial barriers, and poor distribution networks. This limits the penetration of biotech products into large sections of the farming community.

10. International Geopolitical and Trade Pressures

- **Pressure from International Organizations:** India faces pressure from international organizations and trade partners over its stance on biotechnology, especially GM crops. For example, countries with stringent import restrictions on GM products can influence India's biotech policies, limiting its ability to export certain agricultural products.
- **Geopolitical Tensions:** Global geopolitical tensions and trade wars can affect access to essential technologies, research collaborations, and the biotech supply chain. For instance, restrictions on imports of key biotech inputs like research equipment, chemicals, or seeds could impact Indian biotech companies.

Conclusion

The biotechnology sector in India is ripe with potential, but it also faces a wide range of threats that need to be addressed for the sector to thrive. Regulatory challenges, public perception, environmental risks, and economic inequalities are some of the main

barriers to the widespread adoption and growth of biotechnology. Addressing these threats through better regulations, public awareness campaigns, improved research infrastructure, and stronger intellectual property protections can help unlock the full potential of biotechnology in India.

STEEPLE (Social, Technological, Economical, Political, Environment, Legal and Ethical) analysis of Biotechnology: Annexure-VI.

06 NABARD & Biotechnology - Outlook

NABARD is promoting the areas of Biotechnology which are related to the mandate of NABARD in the fields of agri-biotechnology, animal biotechnology and fisheries biotechnology.

Refinance: NABARD provides refinance by way of short term and long-term credit to Commercial Banks, Cooperative Banks, Regional Rural Banks (RRBs) and non-banking finance companies (NBFCs) to meet the credit and financial needs of the food processing industry. The short-term credit (production credit) assists the rural financial institutions to meet the production and working capital needs of farmers, while the long-term credit (investment credit) supports the asset creation and capital formation. Refinance is available for various agriculture and allied activities and off-farm activities including Agri Biotechnology. NABARD also identifies thrust areas from time to time to boost the credit flow to a particular sector, wherein up to 90% / 95% refinance would be available to the eligible institutions.

Direct Finance: Besides refinance, NABARD also provides direct finance to the eligible entities under its different loan products for establishment of infrastructure related to food processing industry.

Rural Infrastructure Development Fund (RIDF): NABARD provides loans to State Governments for creation of rural infrastructure from RIDF set up from out of shortfall in priority sector lending by scheduled commercial banks. Thirty-six infrastructure activities are eligible for funding under RIDF. The eligible activities are classified under three broad categories i.e. (i) Agriculture and related sectors, which are eligible for loans up to 95% of eligible project cost (ii) Social sector, where loan eligibility can be up to 90% of eligible project cost in North eastern and hilly States and 85% of project cost in all other States and (iii) Rural connectivity projects, where loans are extended up to 90% of eligible project cost in North eastern and hilly States and 80% in all other States. Major activities related to Biotechnology are Animal Vaccine Production Laboratories, Animal Disease diagnostic laboratories, Tissue culture nurseries and units, etc. The institutions eligible for RIDF finance are State Governments/Union Territories, State Owned Corporations / State Govt. Undertakings, State Government Sponsored Organisations and Panchayat Raj Institutions/SHGs/ NGOs.

Mapping of credit potential in the district: NABARD maps credit potential in a district through its Potential Linked Credit Plans (PLP). The PLP is a document that identifies the potential for economic activity in a district and outlines how to use that potential to increase credit flow to priority sector. NABARD has been identifying credit

potential for various components under agri-biotechnology viz, Tissue culture, biofertilizers, biopesticides, etc. through PLPs.

- NABARD has been promoting biotechnology not only through refinance, under which tissue culture has been identified as a thrust area for 100% refinance but also by way of a number of promotional supports such as support R&D fund for research projects and for conducting seminars and symposiums. Biotechnology projects can be funded under Farm Innovation Promotion Fund and Rural Innovation Fund
- NABARD has also facilitated formulation of techno economic norms for a few traditional biotechnological activities and prepared model schemes. NABARD has been acting as the subsidy channelizing agency for a scheme by MoA to setup biofertilizeer units.
- NABARD is National Implementing Agency (NIE) for 'Conservation and management of indigenous breeds of cattle and sheep in the wake of climate change in Karnataka' wherein elite cows of indigenous breeds viz. Hallikar, Malnad gidda and Deoni are being selected through performance recording and genomic analysis. The objective of this project is to make available quality germplasm of the indigenous cattle breeds
- Through its subsidiary called NABCONS, consultancy services are also available.
- Discussions with BIRAC, Biotech Parks and Biotech incubation centres on credit need assessment/gap funding for the startups can open a channel to link to NABVENTURES.
- Fund requirements, if any for the national translational research platforms can be supported for creating additional infrastructure needed towards establishing cGMP laboratories or to act as national repositories or to manufacture emergency vaccines/commercially unviable vaccines [e.g. classical swine fever (CSF) vaccine having domestic importance]. In this regard, attempts can also be made to develop revenue sharing models. The revenue out of royalty for clinical trials, product evaluation, rent on repository services, incubation and sale proceeds from vaccines can be shared. This may however require further arrangement with DBT.
- Dialogue with DBT to tie-up with active Farmers Clubs to act as Biotech-KISAN Hubs.
- Roundtable with ABLE (Association of Biotechnology Led Enterprises) / DBT-BIRAC on identifying critical research/piloting needs and linking good leads with R&D fund for assistance. It can be explored under loan cum grant mode along with rights on patents.
- Gap beyond the grant assistance by DBT (75% of cost subject to the ceiling of ₹30 crore) can be considered for support by NABARD under RIDF to

State Governments for setting up Biotech Parks.

- One of the major assignments of NABCONS in 2024 is "Survey and investigation of Shahdara drain for rejuvenation and conservation under Namami Gangey Mission using soil biotechnology and nature-based treatment" and "Preparation of DPR and Project Management Consultancy for anti-rabies Vaccine Production Unit.

Possible Roles of NABARD as an ecosystem enabler:

- Tie-up and devise schemes/ workplans with agencies (DBT/ BIRAC/ABLE etc.).
- Supporting biotech startups.
- Support for applied research and studies.
- Grants schemes for capacity building of FPOs/ farmers to gain knowhow with respect to Agriculture biotechnology.
- Support digital platforms for knowledge dissemination (information about Agri Biotech firms, Agri tech etc.).

Annexure

Annexure-I

Animal Vaccines Developed by IVRI

1. An Improved Brucella Abortus S19 Strain for Control of Bovine Brucellosis
2. Live Attenuated Indigenous CSF Cell Culture Vaccine (IVRI-CSF-BS)
3. Construction of Glycoprotein (GE) Gene-Deleted Mutant Of Infectious Bovine Rhinotracheitis (IBR) Virus Indian Strain for Diva-Based Marker Vaccine
4. Live attenuated Peste Des Petits Ruminants (PPR) vaccine
5. A live attenuated vero cell based goatpox vaccine for protection against goatpox
6. Indigenous live attenuated Sheep pox vaccine (SPPV) (Srinagar 38/2000 strain)
7. Buffalo pox vaccine
8. Camel pox vaccine
9. Sub viral particle based Infectious Bursal Disease Vaccine for chickens
10. Swine (Pig) Septic Pasteurellosis Vaccine
11. Multiple Emulsion Vaccine against Haemorrhagic Septicaemia
12. Vero cell based inactivated JE vaccine candidate for pigs
13. Chicken embryo fibroblast cell culture based live attenuated duck plague vaccine (strain: DPvac/IVRI-19)
14. Vero-Cell Based Live Attenuated Vaccine Candidate Virus For Canine Distemper Using Indigenous Strain
15. Immunoaffinity purified somatic extract of Haemonchus contortus for use as vaccine
16. A novel peste-des-Petits-Ruminants (PPR) viral vector based on the Indian vaccine strain Sungri/96
17. Live Attenuated Canine Parvovirus Vaccine Candidate
18. Lumpi-provac Ind (Lumpy Skin Disease Vaccine)
19. Live attenuated PPR-Goatpox combined vaccine (IVRI)

Diagnostics Developed by IVRI

1. Recombinant antigen based sero-diagnosis of Infectious Bursal Disease by indirect ELISA
2. Recombinant antigen based diagnostic kit for sero-diagnosis of Newcastle disease by single serum dilution ELISA
3. Blue tongue sandwich ELISA kit for antigen detection
4. Synthetic peptide-based antigen capture ELISA for detecting animal rotaviruses
5. Recombinant NS1 protein based indirect IgG ELISA for sero-diagnosis of Japanese Encephalitis in swine and kit thereof.
6. Japanese Encephalitis - IgM ELISA kit for swine
7. Synthetic peptide antigen for diagnosis of Peste Des Petits Ruminants (PPR)
8. Multiple antigenic peptide assay for detection of Peste Des Petits Ruminants (PPR) virus specific antibodies.

9. Recombinant Antigen Based Sero-diagnosis of Infectious Bronchitis.
10. IVRI M PPRV Antigen Capture ELISA Kit
11. Monoclonal antibody-based blocking ELISA for FMD: A Highly Sensitive Assay for Detection of FMD Non-Structural Protein (NSP) Antibodies in All Species.
12. Competitive ELISA Kit for Detection of Antibodies to Bluetongue Virus
13. Competitive-ELISA kit for PPR antibody detection
14. Recombinant antigen (VP7 protein) based indirect ELISA Blue Tongue antibody detection kit.

Annexure II

State-wise details of Bioenergy plants established in past five years (from FY 2017-18 to FY 2021-22) in the country

S. No.	State	Capacity of Bio-energy plants excluding small Bio-gas plants (MWeq)	No. of small Bio-gas plants
1	Andhra Pradesh	43.732	11581
2	Arunachal Pradesh	0	69
3	Assam	0	9641
4	Bihar	13.72	254
5	Chhattisgarh	30.23	6896
6	Delhi	24	0
7	Goa	0.34	8
8	Gujarat	41.31	2454
9	Haryana	72.91	1965
10	Himachal Pradesh	0	115
11	Jammu & Kashmir	0	17
12	Jharkhand		292
13	Karnataka	355.308	21279
14	Kerala	1.6	4208
15	Madhya Pradesh	10.392	13875
16	Maharashtra	513.034	33196
17	Manipur	0	0
18	Meghalaya	0	667
19	Mizoram	0	255
20	Nagaland	0	0
21	Odisha	0	954
22	Punjab	68.159	10557
23	Rajasthan	0	1312
24	Sikkim	0	0
25	Tamilnadu	120.29	1202
26	Telangana	38.74	309
27	Tripura	0	133
28	Uttar Pradesh	48.671	1201
29	Uttarakhand	0.59	3997
30	West Bengal	1.36	448
	Total	**1384.386**	**126885**

Annexure III

State-wise details of Biomass Power and Bagasse/ Non-bagasse cogeneration projects installed in the country upto March 2023

S. No.	State	Total installed capacity of Biomass Power, Bagasse Cogeneration and Non-bagasse Cogeneration Plant as on date (MW)
1	Andhra Pradesh	483.67
2	Arunachal Pradesh	0
3	Assam	2
4	Bihar	124.7
5	Chhattisgarh	274.59
6	Delhi	0
7	Goa	0
8	Gujarat	77.3
9	Haryana	240.66
10	Himachal Pradesh	9.2
11	Jammu & Kashmir	0
12	Jharkhand	4.3
13	Karnataka	1887.3
14	Kerala	2.27
15	Madhya Pradesh	107.347
16	Maharashtra	2584.4
17	Manipur	0
18	Meghalaya	13.8
19	Mizoram	0
20	Nagaland	0
21	Odisha	59.22
22	Punjab	481.15
23	Rajasthan	121.25
24	Sikkim	0
25	Tamilnadu	1012.65
26	Telangana	160.1
27	Tripura	0
28	Uttar Pradesh	2117.26
29	Uttarakhand	130.22
30	West Bengal	338.62
	Total	**10232.007**

Annexure IV

State-wise details of Biomass usage in all TPPs in the country till May' 2023

S. No.	State	Name of the Plant	Capacity (MW)	Cumulative Biomass usage (MT)	State-wise Biomass usage (MT)
1	Uttar Pradesh	National Capital Power Station, Dadri, UP	1820	20617	70977
2		Harduaganj TPS, UP	1265	7392	
3		Feroze Gandhi Unchahar Thermal Power Station, UP	1550	9486	
4		Tanda Thermal Power Station, Ambedkar Nagar, UP	1760	3806	
5		Mahan Al. Unit- CPP, UP	900	29676	
6	Haryana	Yamuna Nagar TPS, Haryana	600	455	20969
7		Rajiv Gandhi TPS, Hisar, Haryana	1200	95	
8		IGSTPP, Jhajjar, Haryana	1500	16008	
9		Mahatma Gandhi TPS, Jhajjar, Haryana	1320	4411	
10	Punjab	Nabha Power Limited (NPL), Punjab	1400	30	180
11		Guru Gobind Singh Super Thermal Plant Ropar (GGSSTP), Ropar, Punjab	840	61	
12		Guru Hargobind Thermal Plant (GHTP), Lehra Mohabbat, Punjab	920	39	
13		TSPL, Mansa, Punjab	1980	50	
14	Maharashtra	Mauda Super Thermal Power Station, Nagpur, MH	2320	24167	27349
15		Solapur Super Thermal Power Station, Solapur, MH	1320	3060	
16		Dhariwal Thermal Power Plant Chandrapur, MH	600	87	
17		GMR Warora Energy Limited, Maharashtra	600	20	
18		JSW Energy-Ratnagiri Maharashtra	1200	5	
19		Sai Wardha Power Generation Limited, MH	540	10	
20	Karnataka	Kudgi Super Thermal Power Station, Bijapur, Karnataka	2400	1912	2248
21		JSW Energy - TPP Bellary, Karnataka	860	336	
22	Andhra Pradesh	Simhadri Super Thermal Power Station, AP	2000	4551	4551

S. No.	State	Name of the Plant	Capacity (MW)	Cumulative Biomass usage (MT)	State-wise Biomass usage (MT)
23	Chhattisgarh	LARA Super Thermal Power Station, Raigarh, CG	1600	489	11464
24		Sipat Super Thermal Power Station, Bilaspur, CG	2980	3882	
25		Jindal super thermal power plant Tamnar, CG	3400	24	
26		Raipur Energen Limited, CG	1370	77	
27		Badadarha TPP, CG	1200	25	
28		Raigarh Energy Generation Ltd, CG	600	25	
29		Bharat Aluminum Company Limited, CG	1740	6942	
30	Madhya Pradesh	Gadarwara Super Thermal Power Station, MP	1600	3140	17603
31		Khargone Super Thermal Power Station, , MP	1320	13417	
32		Jaypee Nigrie super Thermal power plant, MP	1320	577	
33		Jaypee Bina TPS, MP	500	425	
34		Sasan Power Ltd Madhya Pradesh	3960	44	
35	Bihar	Kahalgaon Super Thermal Power Station, Bihar	2340	10	10
36	West Bengal	Budge Budge Thermal Power station, WB	750	181	896
37		Haldia Thermal Power plant, WB	600	90	
38		Farakka super thermal Power plant, Murshidabad, WB	2100	77	
39		Durgapur Steel Thermal Power Station (DSTPS)	1000	501	
40		Bakreswar Thermal power station, WB	1050	22	
41		Sagardighi TPS, WB	1600	25	
42	Rajasthan	Adani Power Rajasthan Limited, Rajasthan	1320	111	7927
43		Shree Mega Power Bewar (CFBC), RJ	344	7816	
44	Odisha	Jharsuguda Captive Power, Odisha	1215	44	64
45		GMR Kamal Ganga, Odisha	700	20	
46	Tamil Nadu	OPG Power Generation Pvt Ltd, Tamil Nādu	420	715	715
47	Jharkhand	Jojobera Power Plant, Jharkhand	427.5	23	23
Grand Total			**64351.5**	**164976**	**164976**

Annexure V

List of Public Sector Undertakings and Autonomous institutions involved in Biotechnology Research and innovations

S. No.	PUBLIC SECTOR UNDERTAKING (PSUS)
1	**Bharat Immunological & Biological Corporation** (A Government of India Undertaking) OPV Plant, Village Chola, Bulandshahr 203203 Uttar Pradesh, India Tel: +91-5732-238758 / 763 (6 lines) Fax: +91-5732-238757 Email:raghavan[dot]s[at]nic[dot]in
2	**Indian Vaccine Corporation Ltd (IVCOL)** New Delhi, Email:ivol_vaccines[at]yahoo[dot]com
3	**Biotechnology Industry Research Assistance Council (BIRAC)** 5th Floor, NSIC Business Park, NSIC Bhawan, Okhla Industrial Estate, New Delhi - 110020 https://www.birac.nic.in/ E-mail address: birac[dot]dbt[at]nic[dot]in Phone: + 91-11-24389600 Fax: + 91-11-24389611

Autonomous Institutions

S. No.	Autonomous institutions
1	**Biotechnology Research and Innovation Council** A Department of Biotechnology Organization https://bric.nic.in/
2	**Regional Centre for Biotechnology** NCR Biotech Science Cluster, Bhankri, Faridabad – 121 004. Haryana http://www.rcb.res.in/

Annexure VI

STEEPLE (Social, Technological, Economical, Political, Environment, Legal and Ethical) analysis of Biotechnology

S. No.	SOCIAL	TECHNOLOGICAL	ECONOMICAL	ENVIRONMENT	POLITICAL	LEGAL	ETHICAL
1.	Attitude: Consumers' attitude is crucial for technology adoption for all stakeholders.	Breakthrough Science: Increasingly newer methods are being experimented and products designed to meet the consumer demand. The science of Biotech. has immense potential to address the challenges being faced today, especially in adaptive climate action.	Biotechnology holds promise to provide solutions to many challenges humankind faces today. Hence it is having high economic significance. Blended finance with public private participation is essential to support R & D & extension works	Sustainability, waste management, green practices aspects that need adhering to environmental standards with corporate ESG guidelines are being included through biotech methods for providing solutions, monitoring etc. With Biotechnology, new breeding techniques (NBT) are available for ensuring more production from limited land and while facing the vagaries of nature.	International trading tariffs, restrictions, price control, protectionists trade policies are prevalent. Post Covid, our nation is looked upon as solution provider through the availability of churning out vaccines in a cost effective and record time. Through the established infrastructure we as a nation have gained recognition and political will has been affirmative for ensuring human health at low cost.	India is having one of the most stringent field trials in place. Legislative issues, such as consumer protection laws, health and safety laws, licensing regulations, intellectual property rights etc. are crucial to promote biotechnology.	Social values, which govern business behaviour play major part in taking developed product to field level.

2.	Acceptance of use of Genetic engineering (GE) in food system has run into controversies across the globe	Governments have recognised the need to make society an active participant in scientific/technological development. Digital Bharat initiatives through OPEN SCIENCE networks/portal to address the knowledge /information reach to farmers is crucial	Workshops/conferences alongwith policy updation is crucial for generating awareness	The GM products, specifically GM plants, will help to (i) reduce greenhouse gas (GHG) emissions, (ii) plant resistance to pests and herbicides (or abiotic stress conditions), (iii) improved yields (iv) enrich foods with nutritional value (v) For farming inclusive of animal health alongwith (vi) e increased economic benefits for farmers. Hence as the next level of evolving science there is need for taking calculated decisions for release of new products and processes in the environment	The GM products, specifically GM plants, will help to (i) reduce greenhouse gas (GHG) emissions, (ii) plant resistance to pests and herbicides (or abiotic stress conditions), (iii) improved yields (iv) enrich foods with nutritional value (v) For farming inclusive of animal health alongwith (vi) e increased economic benefits for farmers. Hence in political sphere all these aspects provide a win win situation	There are enough regulations/ rules that are laid out for biotechnology research and product development. A proper enforcement of these laws along with complimentary norms for consumer protection, health and safety will pave the way for better adoption and acceptance	Ethical issues stem from uneven or inequitable impact of an expanding global economy One of the ethical concerns raised (GMO) is that it is not natural and an is unwarranted tampering with nature.

3	Challenges such as the (a) growing population (b) ecosystem degradation (c) climate change (d) Supply chain disruption (e) upkeep of natural resources (f) nutritional and food security rights have necessitated use of modern technologies and PoPs for overcoming them.	The major issue of technology development is associated with its high cost and timelines. Hence a safety net in the form of IPR is required to be in place that protects the right of technology developers. In our nation most of the R & D is through the Government institutions which undertake research in a structured way.	European nations and other developed countries are much ahead in developing new technologies. As in the Green Revolution technologies, there needs to be more exchange of best use of biotechnology for food security.	Natural ecosystem, germplasm conservation through biotechnology techniques through the repository is gaining through farmers participation in the form of preserving local seeds through seed banks.		Better guidance for innovators on IPR issues	Ethical issues that cover national social, economic and political values of a society has concerns in use in food as GMOs however there is wide acceptance for the use of biotechnology for medicine. Hence there is need to take calculated risk with informed decisions to calibrate ethical values for developing products
4	Post Covid: The perception for biotech methods is changing post pandemic era.	The results developed by the R & D institutions to be extended from lab to field with active participation of consumers/farmers & their collectives	Further strategy with economical gain will be through stable policy environment; good governance; investments in rural infrastructure; agricultural research and extension; and credit and marketing.		Policy makers need to be provided the right information for informed decision making.	Ensuring accessibility to incubation centres with scientific infrastructure for new technological ideas to be confirmed/scaled up for commercialisation/ farmers field trails and to translate in climate action etc. This infrastructure is available through ICAR/ CSIR & ICMR institutions, largely established as having authentic products and processes	The first genetically modified organism (GMO) was introduced into large-scale production in 1996, however with pandemic society is learning to make use of new technologies and is becoming new norm

5	Capacity Building and awareness will bring in acceptance that is based on scientific confirmation of safety of biotech processes and products	Exposure visits, capacity development of stakeholders will pave way for institutionalising an ecosystem of innovation.	PPP mode is prevalent for advent of the technology for which financial institutions to be well equipped with knowledge and its utility.	Nutraceuticals from well-established medicinal and aromatic plants through biotech processes are prevalent offering farmers new crops and processing for increasing their income levels	Creating awareness and capacity building will go a long way for active participation of policy makers		Microorganisms that can tolerate and live in extreme environment have gene pool that can be selectively used for introducing desired traits to combat extreme weather conditions. The population growth demand and increase in frequency and severity of climate events will pave way for more acceptance of the science.
6.	Medical gain: There is wider acceptability of botechnology methods and processes in medicine	Both traditional and modern practices to be strategically used for sustainable progress	There is growing acceptance and interest on biotechnology across the world.		Blending traditional knowledge with modern results is increasingly being recognised by the Government		

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Notes

National Sectoral Paper

Biotechnology

NABARD

Farm Sector Development Department
National Bank for Agriculture and Rural Development
Mumbai