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Potential Of India In The Field Of Biotechnology: An Analytical Study

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Abstract
Biotechnology has been regarded as one of the emerging technological revolutionary areas particularly during the COVID-19 pandemic and post pandemic periods in the last few years. It is an interdisciplinary branch of science where biological organisms or their body parts are used to create specific products for specific use. It is regarded as the technology of the future which may provide a better ecosystem for the living of human and other species on the earth as well as may solve many global problems such as remediation of global hunger, environmental pollution, climate change, energy requirements etc. Global bioeconomy is intimately related with the growth of biotechnology and the industrial chain of "Biotechnology-Bioindustry-Bioeconomy" has been formed. In the last two decades, India has promoted an enabling environment for significant growth in the biotechnology and bioeconomy sector. With the "National Biotechnology Development Strategy: 2021-25", India aims to become a Global Bio-manufacturing Hub by 2025. In FY 2019-20, the estimated value of the biotech industry of India was 63 billion USD which is expected to grow at 150 USD by 2025. The biotech start-up in India is expected to grow from 3500 in 2021 to 10,000 in 2025. To achieve this growth, five major primary biotech sectors have been selected in our country. These are bio-pharma, bio-services, bio-agri, bio-industrial and bioinformatics. These five major primary biotech sectors would contribute to the bioeconomy of the country. Presently, the biotech industry in India is primarily driven by vaccines and recombinant therapeutics. With the establishment of Biotechnology Industry Research Assistance Council (BIRAC) by Department of Biotechnology (DBT), funding has been directed towards emerging technologies in the fields of synthetic biology, quantum biology, nutrigenomics, personalized medicines, microbiome technologies, blue sky research etc. linked with National Development Plans (NDPs) and Sustainable Development Goals (SDGs). DBT has given special emphasis on integrated missions for addressing national and global priorities health, agriculture, clean energy and environment, HRD and entrepreneurship. National Biomedical Resource Indigenisation Consortium (NBRIC) has been set up in collaboration with Confederation of Indian Industry (CII) to foster indigenous innovation and bio manufacturing. India can emerge as a major player in the global supply chain in the field of biotechnology by promoting indigenous innovation and manufacturing of economically and socially relevant biotech products. In 2020, India's share was less than 5% in the global biotech market. In 2025 it is expected that our bio-economy would grow to 150 billion USD against a global estimate of 725 billion which will lead to the share of India to the tune of 21% in the global market. This may make India reach the top 5 biotech countries of the world. This requires strong and strategic partnership among the national research institutions for indigenization of biotechnology with our traditional knowledge in the field of Agriculture, horticulture, livestock rearing and ayurveda. The sharing of research data, technology transfer, and scientific collaboration for innovation etc. are essentially required. An analytical study has been made in this paper with regard to the scopes and prospects of biotechnology as one of the potential areas in the field of science and technology of India for our sustainable future.

Keywords*: COVID-19-Pandemic, Biotechnology, Bioeconomy, Biomanufacturing, Indigenous innovation.*

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I. Introduction

Biotechnology deals with the application of living systems or living organisms for the production of useful products for welfare of human and other desirable species. It is a rapidly growing field which has immense potential in diverse areas of agriculture, health care, food processing, environmental pollution and climate change mitigation etc. In recent decades it is fueling our economic growth to a great extent from recombinant protein production to waste management. Economic prosperity of a nation is largely determined on domestic production, business and commerce. Science and technology have a dominant role in the economic development of a country. In the history of human civilization pandemics played a threat to humanity. The

recent attack of COVID-19 pandemic which was started in China and spread to the whole world affects the society largely and produced new vulnerabilities as well as new opportunities across the globe. It created initial disruption in human activities throughout the world but subsequently led to repair and preparation for the next pandemic from biological sources. In this context, the role of biotechnology as a potential emerging science to combat pandemics as well as production of materials for human consumption is becoming very important. India, as one of the leading countries of the world in the field of science and technology, has immense scope for the sustained growth in the biotechnology sector. Growth in biotechnology, in turn leads to the growth of bioeconomy which is the economic activity out of the biological resources. The market size in this area is growing globally at a very faster rate. To become a leading player in biotechnology and bioeconomy, technology transfer and sharing of knowledge and resources with our strategic global partners are very important. In view of this, issues of biotechnology and bioeconomy should be given due importance while designing our national policies..

II. Biotechnology: The Technology Of Future

Biotechnology is defined as a broad interdisciplinary branch of biological science which uses biological organisms or their body parts for technological applications for creation of specific products or modification of biological processes for specific use. Biotechnology is an emerging field in today's world and this powerful technology can provide an ecosystem for better standard of living of human and other species of the earth and can also solve many global problems. Biotechnology is recognized as the technology of the future as it can be applied to different sectors like food production and processing, healthcare, agriculture, animal science, pharmaceuticals, environmental pollution and conservation, climate change, renewable energy etc. It is not a standalone technology. It is an interdisciplinary technology which involves Plant Science, Animal Science, Microbiology, Genetics, Molecular Biology, Chemistry, Mathematics, Physics, Computer Science, Engineering etc. There are four major branches of biotechnology which are as follows:

- ❖Red biotechnology: This branch of biotechnology is associated with health and medical science. It involves the production of novel drugs, vaccines, stem cells, and other therapeutics for medical use. This branch of biotechnology is also called medical biotechnology.
- ❖Green biotechnology:This branch of biotechnology is associated with agriculture and plant sciences. It involves the production of food materials from animal and plant sources. Production of high yielding food grains and disease resistant crops, pest control and highly nutritious animal foods are the prime targets of this field of biotechnology.It is also known as agricultural biotechnology.
- ❖Blue biotechnology: This branch of biotechnology is associated with the sustainable use of freshwater and marine biological resources and control of aquatic pollution. The earth has most of the areas covered by water and these aquatic resources are very important for our survival. Fisheries and aquaculture areas are two promising technologies in this field. This branch is also known as aquatic biotechnology.
- ❖White biotechnology: This branch of biotechnology is associated with the industrial processes for production of new chemicals or generation of fuels from biological sources for environment friendly vehicles. It is also known as gray biotechnology or industrial biotechnology.

Study of gene, DNA and knowledge of inheritance of biological characters have an important role in shaping modern biotechnology. Gene manipulation through recombinant DNA technology is now being widely used throughout the world for production of high yielding crops, animal products, drugs & vaccines, environment clean up superbugs etc. But there are many areas where biotechnology can be used without genetic manipulation. Biotechnology, therefore, can be divided into two branches based on the use of genetics: i) genetic biotechnology and ii) non-genetic biotechnology.

i. Genetic biotechnology: Genetic biotechnology deals with gene manipulation through selective breeding and genetic engineering. This is a powerful technology which uses recombinant DNA technology for production of new components with desired genetic composition.
ii. Non-genetic biotechnology: Non-genetic biotechnology deals with the individual organism, tissues or whole cells. The examples of non-genetic biotechnology are plant and animal tissue culture, maintenance of animal cell line, microbial fermentation, hybridoma antibodies, immunochemistry etc.

III. Biotechnology And Bioeconomy

Biotechnology could be a major player for sustainable industrial development and inclusive economic growth to achieve UN Millennium Development Goals (MDGs) or Sustainable Development Goals (SDGs). SDG 2 and 3 are particularly important for biotechnology where food security and affordable healthcare for all have been mentioned. The growth of biotechnology started since 1970's based on the research on recombinant DNA technology and monoclonal antibodies. Now, the prospect of this biological technology is so high in industrial and economic growth that the 21st century is called the 'Century of Biology' (Daniel, CV., 2004).

After the COVID-19 pandemic era competition among the biotechnology companies has increased tremendously and the importance of bioeconomy has been felt everywhere. As biotechnology is an interdisciplinary subject, an industrial chain of "Biotechnology-Bioindustry-Bioeconomy" has been formed. Bioeconomy may be defined as an economic activity driven by the research and innovation in the field of bioscience (National Bioeconomy Blueprint, USA, 2012). "The U.S. Bioeconomy: Charting a Course for a Resilient and Competitive Feature" published by the Schmidt Features in 2022, stated that the integration of artificial intelligence and synthetic biology can provide biotechnological solutions in many industrial and economic fields and can boost up the economy to form "4 Trillion Dollar Global Bioeconomy"(Wei X., et.al., 2022).

There are two basic drivers of bioeconomy- i) scientific and technological innovations and ii) pull of social and economic needs. The social and environmental effects of bioeconomy are remarkable. In the past twenty years, the "top ten scientific advances" selected by the 'Science' research journal, it was found that more than 50% were from the field of life science and biotechnology. The rapid growth of technological knowledge supported robust bioeconomy. In recent years, the demand for food, medicines, energy, clean environment etc. leads to growth of bioeconomy. The new concepts such as sustainability, renewability, circular economy, resource efficiency and resilience are being used in bioeconomy.

IV. Current Status Of Global Biotechnology

The leading states across the globe in the field of biotechnology other than India are the United States, Germany, Korea, European Union, Japan etc.

- **United States**: In the United States bioeconomy started mainly in the agriculture and energy sector for the production of agricultural commodities and bio-fuels at the beginning of this century. The use of starch based ethanol and soybean oil improved air quality and reduced greenhouse emissions. By the use of bio-based products new jobs, markets and economic activities created in rural areas of the United States (Davaney L., & Iles A., 2019). Presently, bioeconomy in the United States mainly depends on genetic engineering, DNA Sequencing, bioinformatics, automatic biological sample processing in biomedical, agricultural, industrial and biosecurity fields (Carlson R., 2016). The future of biotechnology and bioeconomy in the United States depends on the growth and expansion of emerging technologies such as synthetic biology (direct engineering of microorganism and plants), protein omics (large scale research and operation of proteins in organisms) and bioinformatics (computational tools for use of biological data).
- **Germany**: In Germany, Bioeconomy is mainly based on agriculture, forestry and fisheries. It is dominated by the private sector with close integration of application oriented technology and the economy. Economy has been integrated with ecology to ensure sustainable utilization of biological resources in Germany. Two main lines of bioeconomy have been proposed in the National Bioeconomy Strategy-2020 of Germany. These are i) to promote bio-knowledge and advanced technology for sustainable and climate neutral bioeconomy and ii) to focus on the biomaterials produced in the industry.
- **South Korea**: In South Korea, the biotechnology industry is mainly organized and implemented by the government. The bioeconomy is mainly focussed on the medical industry including personalized medicine, reproductive medicine, neuroscience, stem cell therapy, medical diagnostics and imaging, nano-biotechnology etc. Functional genomics, proteomics and bioinformatics are also important technology driven areas of bioeconomy in this country.Biosecurity to counter bioterrorism is also another aspect of South Korean bioeconomy. In "Bioeconomic Innovation Strategy-2025", South Korea plans to increase global biotechnology market share from 1.7% in 2015 to 5% in 2025.
- **European Union**: It is a conglomeration of many countries and is highly advanced in biotechnology. EU biotechnology mainly depends on agriculture, fishery, forestry, food, pulp and paper industries, bio-chemicals and bio-energy industries. Biotechnology policy in the European Union focussed on four main aspects: Food, Feed, Forest and Fibre (4Fs). In 2012, the EU published "Innovating for Sustainable Growth: A Bioeconomy for Europe" as a policy statement for biotechnology and bioeconomy. In this document cross integration of life science, agronomy, ecology, food science, biotechnology, nanotechnology, information and communication technology and engineering have been made for achieving sustainable growth in the biotechnology sector. Significant research and innovation have been made in the field of renewable bio-resources. The total turnover of bioeconomy in 28 EU countries was 2.3 trillion EUR in 2015 with the employment of more than 18 million people. Agriculture and food manufacturing accounts for 76% of the bioeconomy share in Europe. In 2018, in the upgraded version of bioeconomic strategy of Europe, three key objectives were put forward- accelerating the development of the bioindustry, promoting the bioeconomic agenda of member countries and urban and rural areas, and protecting ecosystems. In the 2021, 'EU Bioeconomy in 2050' report, emphasis was given on sustainable development, climate neutrality, and inclusiveness in the economic and social realities of the member countries for sustained growth up to 2050.

- **Japan**: Japan is one of the leading bioeconomic countries of the world. In 'Bioeconomic Strategy' published in 2019 and 2022, Japan aims to become the most advanced bioeconomy society of the world in the year 2030 with the targeted turnover of 92 trillion yen (837 billion USD). The concept of expanding sustainable, renewable, circular economy and society by utilizing biotechnology and biological resources have been adopted. Japan tries to form a globally competitive start-up ecosystem for innovation in biotechnology and bioeconomy. Global and Regional Bio-communities have been formed in many places of Japan for research and innovation in the field of biotechnology and bioeconomy.

V. Status Of Biotechnology In India

Biotechnology in India formally started with the establishment of the Department of Biotechnology (DBT) by the Government of India in the year 1986. The department published the Vision Document in Biotechnology in 2000. Biotechnology Strategy-I was published in 2007 and Biotech Strategy-II in 2015. Through these documents and strategy over the last two decades promotes the enabling environment for growth in the biotechnology sector in our country. "National Biotechnology Development Strategy: 2021-25" has been announced recently by the Department of Biotechnology, Government of India with the aim of developing India as a Global Bio-manufacturing Hub by 2025. In FY 2019-20, the estimated value of the biotech industry of India was 63 billion USD which is expected to grow at 150 USD by 2025. The biotech start-up in India would expected to grow from 3500 in 2021 to 10,000 in 2025. There are five major biotech sectors in India. These are bio-pharma, bio-services, bio-agri, bio-industrial and bioinformatics. These five major primary biotech sectors would contribute to the bioeconomy of the country. Presently, the biotech industry in India is primarily driven by vaccines and recombinant therapeutics. Biotechnology Industry Research Assistance Council (BIRAC) was established by DBT for funding in the biotech sector in India in 2012. Funding has been directed towards emerging technologies in the fields of synthetic biology, quantum biology, nutrigenomics, personalized medicines, microbiome technologies, blue sky research etc. linked with National Development Plans (NDPs) and Sustainable Development Goals (SDGs). DBT has given special emphasis on integrated missions for addressing national and global priorities health, agriculture, clean energy and environment, HRD and entrepreneurship. National Biomedical Resource Indigenisation Consortium (NBRIC) has been set up in collaboration with Confederation of Indian Industry (CII) to foster indigenous innovation and bio manufacturing. India can emerge as a major player in the global supply chain in the field of biotechnology by promoting indigenous innovation and manufacturing of economically and socially relevant biotech products. In 2020, share of India was less than 5% in the global biotech market. In 2025 it is expected that Indian bio-economy would grow to 150 billion USD against a global estimate of 725 billion which will lead the share of India to 21% in the global market. This may make India reach the top 5 biotech countries of the world. To achieve this growth, collaboration with multilateral forums such as SAARC, BRICS, ASEAN, BIMSTEC, G-20, G-6 nations and with professional institutions like National Centre for Biotechnology Information (NCBI) of US, European Molecular Biology Laboratory (EMBL), DNA Data Bank of Japan (DDBJ) are essentially required. Collaborating partners are required to initiate mission mode projects in Bioinformatics, Functional Genomics, Encyclopaedia of DNA Elements (ENCODE), Artificial Intelligence and Big Data Analysis etc.

VI. Potential Of India In Industrial And Medical Biotechnology

In industrial and medical biotechnology, fermentation technology is a rapidly growing field and has vast scopes in various industrial productions. It is widely used in the fields of food industry, biofuel generation, brewing, waste treatment, enzyme production etc. since time immemorial, fermentation technology was used in food production. We have developed many indigenous technologies in the fermentation process as evidenced by the production of different "Rasa" in Ayurveda, the traditional medical practices in India.b In modern times fermentation technology is used for the production of cheese, bread, wine, curd etc. The probiotic enzymes and lactic acid fermentation have been widely used to enhance nutritional quality of the food materials. Due to the presence of a large population size in India, biotechnology in the food industry could be of great help in terms of food security as well as enhanced economic growth. This sector can generate employment opportunities in small scale industrial sectors and can also make nutritional self-reliant India. In the biofuel industry, bioethanol is produced by the fermentation of plant products. Using biotechnological processes high quality fuels can be produced in India and our dependence on fossil fuels may be reduced. This will also protect our environment by the production of green energy from the biofuels. India has vast agricultural fields and large amounts of cereals produced in our country can be utilized in the production of large amounts of biofuels and thus make us less dependent on non-renewable resources. Fermentation technology can also be used in sewage treatment. Digestion of solid organic matter by enzymes produces harmless soluble substances and gases. The digested solids can be utilized as fertilizer and volatile gases can be utilized as biogas. In our country large amounts of wastes are produced every day and efficient management of these wastes are very important in terms of human health as well as environmental clean up. In this waste management area, biotechnology has immense potential

which can be harnessed by our country. Generally the term bioremediation is used to denote the uses of microbes and biological products for neutralizing, detoxifying and degrading environmental wastes. Various types of in situ and ex situ bioremediation techniques are used to provide a safer and sustainable solution for the management of environmental toxic wastes. Fermentation biotechnology can also be utilized for the production of several useful enzymes by using various microbes such as bacteria, yeast etc. India is considered as a mega biodiversity country with the presence of a large number of plants, animal and microbial species. The large species are real assets of our country which can be utilized for the production of novel enzymes from thermotolerant organisms or marine organisms with unique properties. Another important area of white and red biotechnology is antibiotic production. Antibiotics can be produced either by natural fermentation process using microorganisms or by a semi-synthetic method. Biocon Limited is the largest antibiotic producing pharmaceutical company of India. In this area, there is huge scope for the generation of start ups to boost industrial productions of antibiotics. One of the important areas of red biotechnology is vaccine production. To protect our body from diseases vaccines play an important role. Presently, vaccines and recombinant protein markets of India are one of the largest in the world. Important players in this field are Serum Institute of India, Indian Immunological Limited, India Serums and Vaccine Limited etc. As vaccines and recombinant proteins have immense market potential, many start ups are working to make India self-reliant and self-sufficient in the field of vaccines and recombinant proteins.

VII. Potential Of India In Aquatic Biotechnology

Our country is rich in aquatic resources with vast water bodies (both marine and freshwater), presence of huge aquatic genetic resources, and a large number of skilled and semi-skilled human resources. Fisheries and aquaculture are very important from the view point of nutritional security, employment opportunities and earning of foreign exchanges. Thus, aquatic biotechnology has immense potential to boost the economy in our country. Fisheries sector of India has grown recently at a higher pace from its traditional livelihood activity to technology driven large scale commercial enterprise. Today, our country ranks second in global fish production with an annual growth of over 7% per annum. We have a coastline of 8118 km with 2.02 million sq. km exclusive economic zone, 0.38 million km stretch of inland rivers and canals, 2.70 million ha of reservoirs, 2.47 million ha of ponds and tanks, 0.43 million ha of beels, 0.34 million ha of derelict water bodies or oxbow lakes and 0.96 million ha of brackishwater area as marine as well as inland aquatic resources. Besides these, diverse cold water resources are distributed in various mountain ranges and high altitude areas. Fisheries and aquaculture sector of India has attracted more attention in recent years in the areas of use of modern biotechnology for sustainable enhanced aquatic productivity. Focus has been given on innovations and technology development in the field of aquatic biotechnology for upscaling of profitability of fish farmers and entrepreneurs. Under the umbrella organization of Indian Council of Agricultural Research (ICAR) several central departments, State Agricultural Universities, and several other Research and Development Organizations are working consistently to achieve desired growth in fisheries and aquaculture sector. Recently several policies have been announced by the government such as National Policy on Marine Fisheries-2017 (NPMF 2017), National Mericulture Policy-2019 (NMP 2019), National Inland Fisheries and Aquaculture Policy-2019 (NIFAP 2019) and National Fisheries Policy-2020 (NFP 2020) to achieve the global leadership in fisheries and aquaculture with sustained growth. Several new schemes have been introduced in this sector to harness the untapped potential of the aquatic resources such as Blue Revolution, Sagarmala, Fisheries and Aquaculture Infrastructure Development Fund (FIFA) and Pradhan Mantri Matsy Sampada Yojana (PMMSY). For sustainable, responsible, inclusive and equitable fisheries and aquaculture, PMMSY has recently been launched with a total investment of Rs. 20050 crores. A new term called Blue Economy has been introduced in India along with this ambitious scheme.

VIII. Potential Of India In Agricultural Biotechnology

India is a highly populous country and the predominant profession of its people is basically agriculture and livestock rearing. We have a vast stretch of fertile land but in the past our life was severely affected by lots of famine in different time intervals. In food production we were not self reliant at the time of our independence from British rule. But after independence due to progress in life science and biotechnology, we generated the Green revolution and became self-reliant in food production. At present India can produce surplus food to feed the hungry people of other countries of the world besides fulfilling our own needs. This is only possible with the miracle of agricultural biotechnology. Our agricultural production has increased multifold in recent times. There are lots of areas where agricultural biotechnology can be applied for our sustainable development. As a primarily agricultural country our farmers developed many traditional plant breeding techniques since time immemorial. But with the infusion of modern biotechnology, the horizon of agricultural productivity is expanding day by day. Disease free plants can be produced by micropropagation techniques. One successful application is the production of disease free banana plants with this easy and relatively inexpensive technique of

tissue culture and micropropagation. Genetic engineering techniques are being used for introduction of disease resistant genes. This technology is also being used for the production of fortified crops with enhanced nutritional properties. Genetically modified crops (GMOs) such as Bt Cotton helps us to become one of the dominant players in cotton production in the world market. High yielding and disease resistant varieties of livestocks are produced in our country with the help of animal biotechnology. Although new technology was always looked at with suspicion, it is now proved that GMOs are not harmful for human health or for the environment. With the help of agricultural biotechnology, pest resistant and drought resistant plants are being produced. Soil management is also possible with the help of biotechnology and crops can be produced in highly acidic or alkaline conditions. Due to the presence of vast agricultural land and high biodiversity, the potential of India in the agriculture sector can be fully utilized to become a global player in food production and livestock management..

IX. Conclusion

Importance of biotechnology as one of the emerging technological revolutionary areas has been felt during the COVID-19 pandemic and post pandemic periods in the last few years. Biotechnology is associated with bioeconomy, the market size of which is growing very fast across the globe. This powerful technology is not only helpful in production of drugs and vaccines for the protection from harmful diseases but also helpful in production of advanced biomaterials for human consumption. This technology can be applied in various fields such as food production, healthcare, fibre production, climate change mitigations, biofuels, bioplastics, biochemicals etc. India with its huge bio resources and efficient manpower can play a leading role in the biotechnology and bioeconomy sector. To achieve this target, biotechnology and bioeconomy should be given due priorities in our national policies. India with its vast biotic resources have enough potential to become a global leader and global superpower with the peaceful use of biotechnology. The more than five thousand years old civilization in India developed many traditional indigenous technologies in the field of agriculture, horticulture, livestock rearing and ayurveda. The infusion of traditional indigenous technologies with modern technologies can achieve sustainable growth and development in our country.

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