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Green Revolution 2.0: How Biological Inputs are Shaping India's Agricultural Exports and Imports?

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ABSTRACT: The Indian agricultural biologicals market was valued at USD 446.26 million in 2022 and is projected to grow to USD 1,269.24 million by 2030. This significant growth is poised to directly impact agricultural practices in India. Biological inputs such as biofertilizers, biopesticides, biostimulants, and other natural products are pivotal in promoting sustainable agriculture by enhancing productivity, improving soil health, and reducing dependency on chemical inputs. These environmentally friendly and economically viable alternatives support plant growth and crop protection, contributing to higher productivity and long-term agricultural sustainability. This paper evaluates the impact of biological inputs on agricultural production and their influence on India's exports and imports, thereby affecting the balance of payments. The findings suggest that improving India's balance of payments requires a multifaceted strategy encompassing both export and import enhancements and advancing the use of biological inputs and biotechnology in agriculture to boost output.

Keywords: Agriculture, Biological inputs, Balance of Payment, Exports, Imports.

INTRODUCTION

The Indian agricultural biologicals market was valued at USD 446.26 million in 2022 and is projected to grow from USD 505.50 million in 2023 to USD 1,269.24 million by 2030, exhibiting a compound annual growth rate (CAGR) of 14.06% during the forecast period (Fortune Business Insights, 2023). Biologicals represent an innovative class of crop protection products that differ fundamentally from chemical counterparts. They degrade rapidly, do not persist in the environment, and are often exempt from Maximum Residue Limits (MRLs), although their efficacy in controlling pests and diseases may be relatively lower than chemical inputs (Chandler *et al.*, 2011; Fortune Business Insights, 2023).

Biological inputs in agriculture encompass living organisms or biological elements introduced to agricultural fields or livestock environments to enhance productivity. These inputs serve multiple purposes, such as improving soil fertility by stimulating soil microbial activity, promoting plant growth through beneficial microbial associations, controlling pests using natural predators, parasitoids, and entomopathogenic nematodes, reducing chemical input usage, and enhancing crop performance under biotic and abiotic stress conditions (Kopittke *et al.*, 2019).

The applications of biological inputs are diverse and include biofertilizers, biopesticides, and biostimulants, all of which contribute significantly to sustainable agricultural practices. Fig. 1 illustrates their potential

uses in improving soil health, fostering plant growth, managing pests, and minimizing reliance on synthetic chemicals. According to recent projections, the Indian biologics market-a subset of biotechnology encompassing products like vaccines, monoclonal antibodies, and gene therapies-was valued at USD 12.3 billion in 2024. It is anticipated to reach USD 24.6 billion by 2033, registering a CAGR of 8% between 2025 and 2033 (www.grandviewresearch.com). Additionally, the bioeconomy of India, which includes all economic activities driven by biotechnological innovation, was valued at over USD 80 billion in 2021 and is expected to grow to USD 150 billion by 2025 and exceed USD 300 billion by 2030 (Imare Group, 2021; MoEFCC, 2022; Sharma & Rathore 2022; Ramarao et al., 2022).

Despite their potential, the adoption of biological inputs in India faces several challenges. One critical limitation is their dependency on proper storage conditions to maintain effectiveness. Biological inputs, being composed of living organisms, are sensitive to temperature and humidity, and improper storage can lead to diminished efficacy (Chandler *et al.*, 2011). Furthermore, the cost of biological inputs is often higher compared to chemical alternatives due to the complexity of production processes, which can deter widespread adoption among cost-sensitive farmers (Kopittke *et al.*, 2019). Capacity constraints in production, distribution, storage, and quality control

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also limit their accessibility and reliability (Imare Group, 2021).

Public investment in promoting biological inputs is significantly lower than subsidies allocated for chemical fertilizers and pesticides, even though policy initiatives like the Paramparagat Krishi Vikas Yojana (PKVY) aim to incentivize sustainable agricultural practices (MoEFCC, 2022; Imare Group, 2021). Additionally, external factors such as climate change exacerbate the challenges faced by Indian agriculture. Rising temperatures and altered precipitation patterns contribute to increased pest and disease outbreaks, leading to greater yield losses (IPCC, 2021). Declining biodiversity further intensifies these challenges by reducing the availability of natural pollinators and biological control agents, which are critical for maintaining ecosystem balance (Potts et al., 2016). Soil health, another vital component of agricultural productivity, is adversely affected by the overuse of chemical fertilizers, resulting in soil degradation and reduced fertility (Lal, 2020).

To address these challenges, a multifaceted approach is necessary. Investments in research and development can advance the formulation and production of more effective and affordable biological inputs. Enhancing farmer awareness and training programs can facilitate better understanding and adoption of these products. Strengthening policy frameworks and increasing public investment in biological inputs can further support their integration into mainstream agricultural practices (Chandler et al., 2011; Kopittke et al., 2019). By leveraging these strategies, India can not only improve agricultural productivity but also contribute to longterm environmental sustainability and economic growth. The objective of this study is to evaluate the impact of biological inputs on agricultural production in India and their subsequent effects on the country's agricultural exports and imports. By analyzing the adoption and effectiveness of biofertilizers, biopesticides, biostimulants, and other natural products, this research aims to provide insights into how these sustainable agricultural practices contribute to enhanced productivity, improved soil health, and reduced dependency on chemical inputs. Furthermore, the study seeks to understand the role of biological inputs in diversifying and increasing export volumes, reducing import reliance, and ultimately improving India's balance of payments. The findings will offer valuable recommendations for policymakers, farmers, and stakeholders to promote sustainable agriculture and strengthen India's position in the global agricultural market.

REVIEW OF INDIA'S BIOLOGICAL MARKET IN LAST DECADE

India's biological market experienced substantial growth between 2010 and 2020, fueled by

advancements in biotechnology, increasing healthcare demand, and proactive government initiatives. This decade marked significant milestones in the development and application of biological products, laying the groundwork for India's emergence as a global biotechnology hub.

Advancements in biotechnology played a crucial role in driving the market's expansion. Breakthroughs in genetic engineering, vaccine development, and monoclonal antibody production were pivotal. The adoption of cutting-edge technologies, such as CRISPR-Cas9 and biopharmaceutical manufacturing, further bolstered India's capabilities in this field (Ramakrishna et al., 2019). The growing demand for healthcare also significantly contributed to market growth. With an increase in the prevalence of chronic and infectious diseases, there was a pressing need for advanced biologics. India's emphasis on affordable healthcare led to the widespread production of biosimilars, making biologics accessible to a broader population (Kumari et al., 2020). Government initiatives further supported the sector's development. Programs like "Make in India" and the Biotechnology Industry Research Assistance Council (BIRAC) incentivized innovation and infrastructure development. Policies that promoted public-private partnerships and offered tax benefits for research activities created a conducive environment for growth (DBT, 2020). The Indian biological market demonstrated remarkable growth, increasing from approximately USD 2 billion in 2010 to over USD 12 billion by 2020. This translates to a compound annual growth rate (CAGR) of approximately 20% over the decade. Significant segments driving this growth included vaccines, biosimilars, biopesticides, and biofertilizers (Imare Group, 2021).

Despite its impressive growth, the sector encountered several challenges. High production costs associated with biopharmaceuticals posed a financial hurdle for manufacturers. Regulatory bottlenecks often delayed product approvals, impeding market entry (Chandurkar *et al.*, 2017).

Furthermore, there was a shortage of skilled workforce handle advanced equipped to biotechnology applications, highlighting the need for enhanced training and education. The developments achieved during the 2010-2020 period established a robust foundation for future advancements. Strategic investments in India's bioeconomy and a focus on sustainable practices are expected to propel the market beyond USD 24 billion by 2033 (www.grandviewresearch.com). Innovations in personalized medicine, synthetic biology, and bioinformatics are anticipated to play key roles in driving this growth, cementing India's position as a global leader in biotechnology.

Table 1: Size of India's biological market.

Year 2010	• Market Size: Estimated at around USD 4 billion.			
	• Key Drivers: Rising pharmaceutical exports, increasing adoption of vaccines, and government support through initiatives like the Biotechnology Industry Research Assistance Council (BIRAC).			
	• Focus Areas: Vaccines, bio-pharma products, and agricultural biotechnology.			
Year 2015	 Market Size: Grew to approximately USD 7 billion. 			
	• Growth Factors:			
	— Surge in demand for biosimilars and monoclonal antibodies.			
	- Expansion of contract research and manufacturing services (CRAMS).			
	— Strong performance in the vaccine segment, with India being a leading supplier globally.			
Year 2020	• Market Size: Reached USD 12 billion.			
	• Significant Developments:			
	- COVID-19 pandemic accelerated research in biologics and vaccine development.			
	— India emerged as a major global supplier of vaccines and biosimilars.			
	— Increased government funding for biotechnology research and infrastructure, as well as			
	initiatives like Make in India.			
Key Trends	• Biopharma Dominance: The biopharma segment accounted for over 60% of the			
	biotechnology market, with vaccines and biosimilars leading the charge.			
	• Global Export Leadership: India became a key exporter of vaccines, supplying over 50%			
	of global demand.			
	• R&D Investment: Significant growth in public and private investment in biotech R&D.			
	Policy Support: Policies like the National Biotechnology Development Strategy foster			
	growth and innovation in the sector.			

IMPACT ON INDIA'S AGRICULTURAL IMPORTS AND EXPORTS

India's imports and exports are significant components of its economy, reflecting its trade relationships and economic policies. The impact of biological inputs on India's imports and exports can be understood by analyzing the trends in trade and economic activities over the years. India is a major exporter of various goods, including textiles, agricultural products, pharmaceuticals, and software services. The textile industry, one of the oldest and largest sectors in the country, has contributed significantly to export revenues. It employs millions and plays a critical role in sustaining rural livelihoods and enhancing economic growth (Ramakrishna et al., 2019).

Agricultural products, including rice, wheat, and spices, are another major export category. These exports have been influenced by the adoption of biological inputs, which improve soil fertility, reduce dependency on chemical fertilizers, and enhance crop yields. For example, biopesticides and biofertilizers have been promoted to improve the sustainability of Indian agricultural exports, particularly in organic farming (Kumari et al., 2020). The pharmaceutical sector, bolstered by advancements in biotechnology, has also seen remarkable growth. India's production of biosimilars and vaccines has positioned it as a global leader affordable healthcare solutions in (www.grandviewresearch.com).

India has recently expanded its export portfolio to include defense products, such as missiles and aircraft. This growth is part of the "Make in India" initiative, which aims to boost domestic manufacturing and increase exports across various sectors, including agriculture and industrial goods (Department of

Biotechnology, 2020). On the import side, major categories include crude oil, gold, coal, electronic components, and industrial machinery. These imports are essential for meeting domestic demand and supporting industries such as energy, transportation, and manufacturing. India relies heavily on crude oil and coal to meet its energy requirements, making these commodities critical to its economy. However, this reliance has significant implications for the country's trade deficit and foreign exchange reserves (Imare Group, 2021). Gold and precious metals form another significant portion of imports, driven by cultural demand and the jewelry industry. Electronic components and industrial machinery are crucial for India's growing technology and manufacturing sectors. Recognizing the dependency on imports, especially from countries like China, the Indian government has focused on reducing reliance through initiatives such as "Make in India" and the promotion of local manufacturing (Chandurkar *et al.*, 2017).

Biological inputs in agriculture could influence this trade dynamic by reducing the need for chemical fertilizer imports and increasing the export potential of organic and sustainable agricultural products. By fostering the domestic production of biological inputs, India can enhance agricultural productivity, improve trade balance, and achieve greater self-reliance in critical sectors. In the fiscal year 2023-24, India's agricultural exports amounted to \$48.9 billion, a decline from \$53.2 billion in 2022-23. Despite this decrease, India maintained a 2.4% share of the world's agricultural exports in 2022. Major export items included cereals such as rice, wheat, and maize, as well as vegetables, spices, cashew, oilcake/meals, tobacco, tea, and coffee. These exports reflect the diverse and rich agricultural base of the country, showcasing its capacity to produce a wide range of crops and products that are in demand globally.

On the import side, India's agricultural imports in 2023-24 were valued at \$32.8 billion, down from \$35.7 billion in the previous fiscal year. This positions India as the world's eighth largest importer of agricultural products. The primary imports include edible oils, pulses, and fruits, which are essential for meeting the domestic demand and supplementing local production. These imports highlight the country's need to balance its agricultural economy by bringing in products that may not be produced in sufficient quantities domestically.

The decrease in both exports and imports indicates shifts in global market dynamics, domestic agricultural production, and trade policies. The export portfolio, with its focus on cereals, high-value items like spices, and traditional products such as tea and coffee, underscores India's strong agricultural heritage. Conversely, the import of essentials like edible oils, pulses, and fruits points to areas where domestic production needs to be augmented to meet the population's needs.

This balance between exports and imports is crucial for India's agricultural economy, impacting everything from farmer incomes to food security. As global and domestic conditions evolve, these figures are likely to change, reflecting ongoing adjustments in the agricultural sector. The interplay of exports and imports will continue to shape the agricultural landscape, influencing policy decisions and economic strategies aimed at sustaining growth and stability in this vital sector.

Table 2 reflects the total exports, total imports and balance of payment situation (exports minus imports) of India for financial years 2010-11 to 2020-21. The balance of payment as seen is in minus; meaning imports are more than exports resulting in deficit (erosion of foreign currency). For a fast developing country like India, it is important to improve the balance of payment situation by increasing exports and improving its international trade.

 Table 2: Balance of Payment of Principal Commodities (Value in Rupees Crores).

Year	Total Exports (in Rupees Crores)	Total Imports (in Rupees Crores)	Balance of Payment (in Rupees Crores)
2010-11	1142922	1683467	-540545
2011-12	1465959	2345463	-879504
2012-13	1634318	2669162	-1034844
2013-14	1905011	2715434	-810423
2014-15	1896445	2737087	-840642
2015-16	1716384	2490306	-773922
2016-17	1849434	2577675	-728241
2017-18	1956515	3001033	-1044518
2018-19	2307726	3594675	-1286949
2019-20	2219854	3360954	-1141100
2020-21	2159043	2915958	-756915

(Source- complied by the researcher from data available on website of Directorate General of Commercial Intelligence and Statistics.)



Fig. 1. India's Exports, Imports and Balance of Payment.

Fig. 1 reflects the exports, imports and balance of payment situation of India from the year 2010-11 to 2020-21. The red line in the graph reflects the Imports, the blue line in the graph reflects the exports while the

green line shows deficit in balance of payment. it is evident that in order to improve the balance of payment situation, India needs to improve its position in international trade.

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Managing deficits in international trade is crucial for maintaining a stable economy. To address trade deficits, India needs to adopt a range of strategies that promote exports and reduce dependency on imports. One effective method is to promote export-oriented industries. By supporting industries with export potential through incentives, subsidies, and access to financing, the government can increase the country's export capacity. Initiatives like "Make in India" have been introduced to boost manufacturing and enhance exports across various sectors (Department of Commerce, 2021). Diversifying export markets is another essential strategy. Over-reliance on a few trading partners can make an economy vulnerable to external shocks. Exploring new markets, negotiating trade agreements, and participating in international trade fairs can help India expand its export base and increase trade volumes. For instance, India's outreach to African and ASEAN markets has shown promising results (Chandurkar et al., 2017). Encouraging domestic production is critical to reducing import dependency. By promoting local industries to produce goods that are currently imported, India can lower its import bill. Policies supporting small and medium enterprises (SMEs) and fostering innovation are key to achieving this goal. For example, the government's Production Linked Incentive (PLI) scheme is designed to boost domestic manufacturing (Imare Group, 2021).

Investment in technology and infrastructure is vital for improving the competitiveness of domestic products. Advanced technology and robust infrastructure can reduce production costs and enhance the quality of goods, making them more appealing in both domestic and international markets. Studies have shown that countries with higher infrastructure investments have more competitive export sectors (Ramakrishna et al., 2019). Implementing tariffs and quotas can also help manage trade deficits, though this approach can be controversial. Tariffs make imports more expensive, encouraging consumers to buy domestic products. Similarly, quotas can limit the quantity of specific goods that can be imported. These measures must be carefully designed to avoid trade disputes and ensure compliance with international agreements (Kumari et al., 2020; Ramu & Asokhan 2022; Balkrishna et al., 2021).

Negotiating trade agreements plays a crucial role in reducing trade barriers and improving access to foreign markets for Indian exports. Bilateral and multilateral agreements can provide a framework for more favorable trade terms, enhancing the competitiveness of Indian products globally. Recent trade agreements with Australia and the UAE demonstrate the potential benefits of such initiatives (www.grandviewresearch.com).

Adjusting exchange rates is another strategy that can influence trade balances. A weaker currency makes exports cheaper and imports more expensive, potentially improving the trade balance. However, this must be managed carefully to avoid triggering inflation or impacting foreign investment (Chandurkar *et al.*, 2017).

Attracting Foreign Direct Investment (FDI) can help reduce reliance on imports by boosting local production. A favorable business environment, coupled with streamlined regulations, can encourage FDI and drive economic growth. FDI in sectors such as electronics and pharmaceuticals has already shown significant benefits (Department of Commerce, 2021). Investing in human capital is equally important. By enhancing the skills of the workforce through education and training, India can improve productivity and foster innovation. Skilled workers are better equipped to create high-quality, competitive products for the global market (Imare Group, 2021). Focusing on quality and branding can make Indian products more competitive against imports. Building strong brands and ensuring high quality can help Indian goods stand out in the global market, increasing their appeal to international buyers. For example, Indian textiles and spices have leveraged branding to capture niche markets (Ramakrishna et al., 2019). Finally, regularly assessing trade policies is essential for managing trade deficits effectively. Continuous monitoring and evaluation can help identify areas for improvement and ensure that implemented strategies are yielding the desired outcomes. Trade policy reviews by organizations like the WTO can provide valuable insights for India's trade strategy (Kumari et al., 2020).

CONCLUSIONS

In conclusion, improving India's balance of payments requires a comprehensive and multi-faceted approach that targets both exports and imports while leveraging advances in biological inputs and biotechnology to enhance agricultural productivity. Diversifying the export basket by investing in high-value sectors such as electronics, pharmaceuticals, and renewable energy technologies essential. is Enhancing export competitiveness through reduced logistics and compliance costs, along with improved access to global markets via favorable trade agreements, is crucial. Promoting startups and innovation in high-demand industries like artificial intelligence, biotech, and clean energy can further stimulate agricultural production and increase export volumes. Reducing import dependence by promoting domestic manufacturing and expanding renewable energy capacities to lessen reliance on imported crude oil and coal is vital. Strategies to lower oil imports should include promoting energy efficiency and alternative fuels, while boosting domestic oilseed production can significantly reduce edible oil imports. Integrating biotechnology and advanced biological inputs into agriculture, such as genetically modified crops, precision farming, and biofertilizers, can optimize resource use, reduce environmental impact, and increase crop yields. These advancements will enhance agricultural exports and ensure domestic food security. By adopting this multi-faceted strategy, India can improve its balance of payments, create a more resilient and sustainable economic framework, and ensure long-term economic stability and growth.

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