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# Recent Agri-Bio Innovations in India: A Critical Review

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**ABSTRACT: Agriculture serves as the backbone of global economies, directly or indirectly supporting billions of lives. Conventional farming methods face increasing pressure from climatic changes, resource depletion, and population growth. In India, approximately 160 million hectares are under cultivation, with two-thirds reliant on monsoons, underscoring the urgent need for improved water management systems. Advanced agri-bio innovations have emerged as critical solutions, with technologies such as the Pusa Decomposer Powder reducing stubble burning and enhancing soil fertility, and the Pusa Hydrogel improving water retention in arid regions. Biochar noted for its carbon sequestration potential and soil benefits, has demonstrated improvements in soil structure, water-holding capacity, and nutrient retention, offering sustainable options for addressing environmental concerns. India's government initiatives, including the Soil Health Card Scheme and PM-KISAN, complement these advancements by providing resources and financial support to farmers. Globally, the agricultural biotechnology sector has expanded, particularly in genetically modified crops, with notable challenges such as environmental safety and food security. India has adopted agri-bio innovations like nano-urea, laser land leveling, and automated monitoring systems, which contribute to sustainable agricultural practices. The sector anticipates a 70% increase in food demand by 2050, driven by population growth from 7.3 billion today to 11 billion. By integrating innovations, such as genome editing and omics, alongside supportive policy frameworks, Indian agriculture can achieve substantial progress, addressing food security challenges while ensuring sustainability.**

**Keywords:** Biochar, Climate resilience, Pusa Decomposer, Resource optimization, Soil fertility.

## INTRODUCTION

Agriculture is the foundation of worldwide economies, supporting billions of lives straightforwardly or by implication. Conventional cultivating strategies are progressively tested by changing climatic circumstances, decreasing normal assets, and a quickly developing populace with expanded water use for water systems, soil debasement, and synthetic overflow are only a portion of the unseen side-effects influencing the scene. The disintegration of the farming asset base because of these elements is remembered to have contributed, to some extent, to a log jam in yield development that started during the 1980s (Mariani and Kaji 2016). These ecological expenses recommend that the main green upset's drawn-out progress might be in danger. A progression of quick mechanical and agronomic advances that occurred after The Second Great War — changed agriculture, saving in excess of a billion group from starvation and making way for the total populace to increment from 3 billion in the last part of the 1960s to an expected 7.3 billion today. Regardless of this phenomenal development, notwithstanding, there are huge difficulties to the proceeded with extension of this first green upheaval, and somehow or another it has been the survivor of its own prosperity. The important to deliver more food stays earnest (Okechukwu and Stanley 2024). The total populace is supposed to reach almost 11 billion by 2050, addressing an expansion in rural interest of roughly 70% — a figure that must be met with

another unrest in farming. Advances, for example, high level sensors and checking gear can now permit farmers to screen crops more exactly and consistently than previously. The information gathered by these advances can empower ranchers to settle on additional compelling and key choices that increment efficiency with decreased influences on the climate. In the interim Agri-bio developments have arisen as an answer for improve efficiency, lessen ecological impressions, and guarantee maintainable cultivating rehearses (Mariani and Kaji, 2016). These advancements range biotechnology, computerization, soil wellbeing the executives, and waste decrease strategies.

India grapples with major obstacles in guaranteeing sufficient food supplies for its people. These challenges are worsened by dependence on input-driven investments and a distribution system that is less efficient compared to China's direct trade practices. The country's measures to address fluctuations in global food prices, particularly through the enactment of the Public Food Security Act, have raised concerns as well. As India, a basically agrarian economy, has embraced agri-bio innovations like robots for pesticide showering, Pusa Decomposer Powder for stubble the executives and laser land levelers for productive water utilization. This article dives into key advancements in India and around the world, featuring their commitments to supportable rural practices.

## MATERIAL AND METHODS

This systematic review aims to analyze and consolidate existing research on approaches for evaluating the present study. Secondary data analysis refers to the examination of data that has been previously collected by other researchers (Srivastava and Lal 2021; Kumar *et al*., 2022; Lal *et al.,* 2023). A thorough literature search was performed across various databases, including Google Scholar, IEEE Xplore, PubMed, Research Gate, Science Direct, Taylor & Francis, Elsevier & Springer Nature.

## RESULT AND DISCUSSION

**Sustainable Practices.** Indian Agri-Bio Innovations aimed at promoting sustainable and efficient agricultural practices. These include bio-fertilizers and bio-pesticides, which serve as eco-friendly alternatives to chemical inputs by enhancing soil fertility and pest control without environmental harm. The Pusa Hydrogel improves water retention in soil, helping crops withstand water scarcity, particularly in arid regions. Laser land levelers ensure precision leveling of fields, enabling uniform water distribution and improving irrigation efficiency. The Pusa Decomposer accelerates the breakdown of crop residues, mitigating stubble burning and enhancing soil health. Biochar, a carbon-rich product, boosts soil fertility, sequesters carbon, and reduces greenhouse gas emissions. Additionally, nano-fertilizers and nano-urea offer advanced nutrient delivery at the nanoscale, minimizing waste and environmental impact while increasing crop productivity. Collectively, these innovations reflect India's strides in integrating biotechnology with sustainable farming to tackle challenges like climate change, resource scarcity, and food security (Fig. 1).

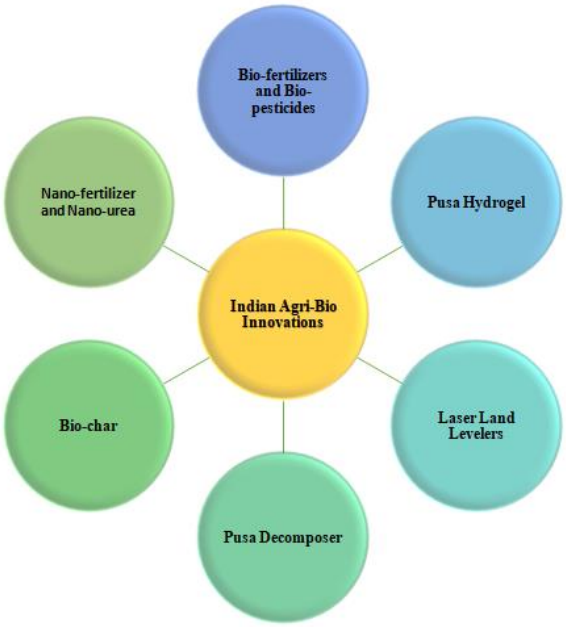


**Fig. 1.** Top Indian Agri –bio innovation.

**Pusa Decomposer Powder:** Crop buildup the executives represent a critical test in reasonable agriculture, with conventional works on causing natural corruption and soil wellbeing weakening. Pusa Decomposer, created by the Indian Rural Exploration Organization (IARI) New Delhi India, arises as an inventive answer for speed up crop build-up disintegration diminishing stubble consuming and soil contamination. This microbial consortium, containing helpful parasites, speeds up the breakdown of intense lignocellulosic buildups into natural matter and supplements, advancing the dirt. The application includes blending Pusa Decomposer in with crop build-ups during or post-collect, advancing fast disintegration and change of deposits into humus and fundamental supplements. This eco-accommodating methodology upgrades soil fruitfulness, further develops design, and supports gainful soil organisms, lining up with feasible cultivating rehearses. By moderating natural contamination from consumption and enhancing soil wellbeing, Pusa Decomposer remains a promising technique for reasonable harvest buildup for the executives, cultivating farming manageability and ecological preservation (Indian Agricultural Research Institute [IARI], 2024).

**Biochar:** Biochar is a nutrient-dense substance derived from biomass that is being considered for soil transformation while also increasing harvest yields and carbon sequestration. This article outlines the possible advantages of biochar usage,

emphasizing its utilization in farming (Table 1). It appears biochar utilized for soil correction works to supplement the thickness of soils, and water holding limit, diminishes compost prerequisites, improves soil microbiota, and increments crop yields (Allohverdi *et al.,* 2021). Moreover, biochar use has numerous ecological advantages, monetary advantages, and is a possible task to carry out in carbon credit frameworks. Biochar (otherwise called biocarbon) may hold the response to these basic prerequisites. The main evidence of biochar application as a soil improver was Terra Preta, also referred to as "India black earth," which enhanced the soil characteristics through ancient Indigenous communities. Terra Preta is a type of soil originally discovered in Western Amazonia. It is distinguished by its dark color, its significant structural stability due to higher carbon levels, and its rich nutrient content linked to increased microbial activity. The utility of the biochar from various waste is a promising way of recycling and it could improve the health of the degraded soils, poor soils and barren lands (Elangovan *et al*., 2022).

**Table 1: Soil Benefits of Biochar: Description and Effects on Soil Properties (Allohverdi *et al.,* 2021).**

| Soil Benefit of Biochar | Description |
|---|---|
| **Soil Structure and Aggregation** | Biochar improves soil aggregation and structure by increasing porosity, which aids in better aeration and water infiltration, especially in compacted soils. |
| **Water Holding Capacity (WHC)** | Biochar increases the WHC in soils due to its porosity, which helps retain water, especially in sandy or drought-prone soils, making it beneficial for drought management. |
| **Nutrient Retention and Availability** | Biochar enhances nutrient retention, especially for nitrogen, phosphorus, and potassium, which helps reduce nutrient leaching and improves soil fertility. |
| **Soil pH Modification** | Biochar can either increase or decrease soil pH, depending on its feedstock and pyrolysis conditions, making it useful for ameliorating soils with extreme pH levels. |
| **Microbial Health and Diversity** | Biochar promotes beneficial microbial populations, including mycorrhizal and rhizobial communities, which help in mineral rotation, soil detoxification, and vegetation development. |
| **Improvement in Natural matter** | Biochar contributes to the increase regarding natural material within the earth, which supports the soil microbiome, and helps prevent anaerobic conditions that lead to nitrogen loss. |
| **Long-Term Soil Health** | The stability of biochar in soils means it persists over several years, improving land conditions and lowering the requirement for frequent reapplications compared to traditional fertilizers. |
| **Reduction in Soil Salinity** | Biochar can help alleviate soil salinity by binding with sodium ions (Na+), preventing them from being absorbed by plants, thus improving plant health in saline soils. |

**Pusa Hydrogel:** Pusa-Hydrogel is a partially engineered, interconnected, altered cellulose-derived negatively charged polyacrylate highly absorbent polymer. In India there is around 160 million ha of land under development in which there is around 39 million inundated underground water, 22 million watered through channels, streams and around two third of land is subject to storm and the accessible water system the executive's framework in India is poor as the significantly rehearsed type of water system is flood water system bringing about consumption of ground water table. Government ought to likewise advance such a good thought of the researcher of IARI, New Delhi and assist the ranchers with effectively getting to the best development of the ten years. This development is helpful for the endurance of yield in most horrendously terrible circumstances likewise i.e., dry spell and high temperature and furthermore appropriate at each Indian soil conditions (Anupama and Parmar 2012).

**Government Efforts for Agriculture in India**

The administration in India has implemented various programs to strengthen rural regions, such as:

**The Prime Minister Farmer Honor Fund (PM-KISAN)**, launched in February 2019, is a direct income support program for farmers. This initiative provides small and marginal farmers with direct monetary transfers of six thousand rupees (about eighty-four dollars) yearly, disbursed in three payments. The initiative seeks to furnish financial assistance to agricultural producers and enhance their income.

**Prime Minister's Crop Insurance Scheme (PMFBY)**: The Pradhan Mantri Fasal Bima Yojana (PMFBY) is an agriculture insurance initiative inaugurated in 2016. It provides coverage and safeguards for farmers against crop losses resulting from natural disasters, pests, and illnesses.

Premium rates are subsidized to guarantee affordability for farmers. The program assists farmers in mitigating the risks associated with crop failure and ensures financial stability (Kumar, & Verma, 2023). .

**The Soil Health Card Scheme**, initiated in 2015, aims to assess and monitor the nutritional composition of agricultural soils. Farmers receive soil health cards that include information on soil fertility, nutritional shortages, and recommendations for optimal fertilizer application. This effort assists farmers in making informed decisions about soil management and improving crop output.

**e-NAM (National Agriculture Market)**: e-NAM is a digital trading platform for agricultural commodities. Launched in 2016, it seeks to create a cohesive national marketplace for agricultural products by connecting the existing Agricultural Produce Market Committee (APMC) markets nationwide. Agricultural producers can engage in digital trade, obtain transparent pricing, and capitalize on enhanced market opportunities.

**The Paramparagat Krishi Vikas Yojana (PKVY)** advocates for organic agriculture throughout India. It provides financial assistance to farmers for the adoption of organic farming practices and certification acquisition. The program promotes the utilization of organic inputs, crop rotation, green manure, and vermicomposting, in addition to various organic farming methods.

## CONCLUSION

Agri-bio innovations are redefining agriculture by merging sustainability with productivity. India's grassroots approaches like Pusa Decomposer Powder and laser leveling have empowered small farmers.

**1. Policy Support:** Governments must create favorable policies to promote agri-bio innovations.

**2. Collaborative Research:** Encouraging partnerships between Indian and global researchers can accelerate innovation.

**3. Farmer Training:** Ensuring farmers are well-trained in using these technologies is crucial.

By fostering innovation, knowledge-sharing, and sustainability, agriculture can continue to meet the growing demands of humanity while preserving the planet.

## FUTURE SCOPE

This research expands the understanding of biotechnology's role in Indian agriculture by considering ongoing advancements, strategic guidelines, and the potential to benefit small-scale farmers (Okechukwu and Stanley 2024). The outlook for biotechnology in Indian agriculture is promising, offering opportunities for substantial progress and contributions to the global economy. Specifically, plant biotechnology holds immense potential to enhance crop health and yield, address food security challenges, and cater to India's rising demand for food and nutrition. Achieving this potential requires leveraging innovative genetic resources, genome editing technologies, and advancements in omics, alongside developing precise, data-driven, and automated screening methods. Biotechnology has profoundly influenced Indian agriculture through the adoption of genetically modified crops and advancements in genetic resource management. Tissue culture, a fundamental biotechnological method, has also significantly contributed to industry growth and market needs, though it holds even greater untapped potential. Plant biotechnology has been instrumental in boosting crop productivity and responding to increasing food and nutritional demands, particularly amidst population growth. The agricultural biotechnology sector, especially in genetically modified crops, has experienced notable expansion but faces hurdles such as food safety and environmental sustainability. Addressing these challenges early is crucial. Borah highlights the Indian government's role in fostering this sector's development, while McKinney examines ethical, economic, and political dimensions of agricultural biotechnology, focusing on Bt cotton in Gujarat. Their work underscores the importance of managing natural resources effectively and driving economic reforms in agriculture. Collectively, these studies emphasize the government's vital role in restructuring and advancing biotechnology practices in Indian agriculture.

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