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Managing Sustainable Agriculture Practices in India Through Microbial Developments, 2023: A Literature Review

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ABSTRACT

"Management of Sustainable Agriculture Practices: Microbial Developments in India in 2023" is targeted towards managing the recent developments in microbial technologies, its application in the area of sustainable practices in agriculture in India. Those reviewed here are, various scholarly articles, case studies, government reports/reviews brought to light in the year 2023-2024. The contribution of microbial innovations in improving soil fertility/health is highlighted. The key findings are a guiding factor towards how biotechnology can be united with age-old agricultural techniques and can majorly add value to sustainable agriculture.

Key limitations of the review, methodology adopted, key findings and recommendations are discussed with an aim to give an extensive overview of the subject.

INTRODUCTION

Sustainable agriculture practices are important for India's economic prosperity and food security. Amalgamation of age-old farming techniques and modern biotechnology are looked at as a promising prospect in giving solution to the present issues such as degradation of soil, infestations due to pests and low productivity of crops. This study aims at inspecting the innovations in the area of microbes with the main focus being that to transform farming practices in Indian states. Studying the recent literature on microbial and biotechnological innovations, the paper endeavours to give practical knowledge on the subject.

LITERATURE REVIEW

Synergizing Biotechnology and Natural Farming:

This study talks about mixing of biotechnological methods with traditional farming methods to improve agricultural sustainability (Frontiers in Plant Science, 2024). The authors have talked about microbial technologies like biofertilizers and biopesticides that can boost crop production and decrease the detrimental effects that are otherwise caused to the environment. Available at: Frontiers in Plant Science

Kunapajala: Ancient Manure:

This paper studies Kunapajala, an age-old manure in the history of India and how its benefits and strength can contribute in modern Indian agricultural lands (Frontiers in Sustainable Food Systems, 2022). The process of making it is through fermentation and liquefying the manure which originally is animal and plant waste. As per tradition, it assisted in improving the fertility of soil. Recent developments in studies indicate that Kunapajala consists of microbes that boost plant growth so as to safeguard them against infestation by pests and diseases (Frontiers in Plant Science, 2024).

Cypermethrin Toxicity and Microbial Degradation:

This research delves into the effects of cypermethrin- a pesticide on the environment and consecutively its degradation by microbial routes (Journal of Applied Microbiology, 2023). The study focuses on certain microbe strains that could potentially be able to break down cypermethrin and convert into safer substances and further provide a sustainable way in regulating pesticide pollution especially in the states of Haryana and Punjab.

Innovative Integrated Pest Management:
This paper will discuss strategies for pest management that cause an increase in crop production in a sustainable manner with specific reference to the North East India (Pranab Dutta et al., 2023). It also focuses on combining of microbial biopesticides and various historical pest control methods. These would help in the reduction of use of chemically manufactured pest control use thus enhancing the overall crop's tolerance level (Pranab Dutta et al., 2023).

Microbial Maestros:
This detailed review stresses on the role played by the soil microbes in an environment-conducive sustainable agriculture (Abdul Kapur Mohamed Mydeen et al., 2023). The authors have described multiple microbial actions like nitrogen fixation, phosphorous solubility and decomposition of organic matter with the application of microbes with a goal to maintain and sustain soil fertility. (Abdul Kapur Mohamed Mydeen et al., 2023).

Innovations in Modern Nanotechnology for Sustainable Agriculture:
In this paper use of nanotechnology for the improvement of microbial functions in sustainable agriculture is discussed (Rajiv Periakaruppan et al., 2023). Nanotechnology comes with the boon of enhancing the efficiency and specific release of microbial inoculants, biofertilizers and biopesticides (Rajiv Periakaruppan et al., 2023).

Revisiting the Modern Approach to Manage Agricultural Solid Waste:
This study allows insights into innovative ways to deal with agricultural solid waste with the help of microbial processes (Pratichi Singh et al., 2023). The authors talk about diverse techniques of microbial conversion of the agricultural waste into key resources like compost and bioenergy (Pratichi Singh et al., 2023).

Novel Bacteriophage-Based Food Packaging:
This research explores the usage of bacteriophages for the microbial breakthrough in food packaging which has potential to ultimately enhance the food safety practices (Rajesh V. Wagh et al., 2023). The bacteriophages are a class of viruses that particularly aim at bacterial pathogens that furnish simple and productive method for checking illnesses that are borne through food (Rajesh V. Wagh et al., 2023).

Advancements and Innovations in Harnessing Microbial Processes for Enhanced Biogas Production:
This research paper has discussed the most upcoming developments concerning the use of microbial actions to improve biogas production (Ankita Das et al., 2023). Emphasis by the authors is laid upon the ability if microbial organization that could be put in place to improve the productivity of biogas production and its output. These would act as systemic solutions for sustainable energy (Ankita Das et al., 2023).

Benefits of Rhizobacteria and Endophytic Bacteria:
The review highlights the collective effects of (PGPR) Plant Growth Promoting Rhizobacteria and Endophytic Bacteria for a sufficient and continued agricultural purpose (Jagjot Kaur & Gulab Pandove, 2023). The authors have thought upon the usefulness of these microbes for strengthening the growth of plants, nutrient digestion, resistance to stress through various studies (Jagjot Kaur & Gulab Pandove, 2023).

Leading Businesses and their Production Methods:
Making sure that there is consistency and easy obtainability of biopesticides in sustainable agriculture is of paramount importance for the success of commercialization. A few mass production methods widely adopted are discussed here:

Solid State Fermentation Method: This robust method is used in the production of fungal pesticides like *Trichoderma* spp, Beauveria bassiana and Metarhizium anisopliae. The production process involves selecting a substrate like wheat bran, corn cobs, rice etc., its inoculation with microbial culture, incubation, harvest and formulation in the forms of powders, granules or liquids.

Submerged Fermentation: This method is used for the production of bacteria and yeast in a liquid medium. It works by preparation of the required medium for growth, sterilization of the medium, inoculation, fermentation in a bioreactor or fermentor, harvesting and further processing/packaging.

Bioreactors:
This involves the use of bioreactors to cultivate micro-organisms in batch fermentation or continuous fermentation methods. Microbial biomass is fermented in a bioreactor, harvested and formulated in powder,

granules or liquid suspension forms.

Leading Producers of bio pesticides and biofertilizers are Biotech International Ltd., New Delhi, International Panaacea Ltd., New Delhi, Ajay Biotech (India) Ltd., Pune, Kan Biosys Pvt. Ltd., Pune, Bharat Biocon Pvt. Ltd., Chattisgarh, Excel Crop Care Ltd., Mumbai, Govinda Agro Tech Ltd., Nagpur, Indore Biotech Inputs and Research Pvt. Ltd., Indore, T. Sanes and Company Ltd., Coimbatore and Hindustan Bioenergy Ltd., Lucknow

These businesses are putting up significant efforts towards the advancement of the microbial biotech market in India.

Entrepreneurship Opportunities for Agriculture Graduates and Rural Youth of India:
The scope of this review is to visualise the prospects for entrepreneurship in the field of agriculture, stressing more on the part played by microbial innovations (Shravan Manbhar Haldhar et al., 2023). This review highlights the potential available for youth entrepreneurs who can capitalise microbial products for sustainable agriculture (Shravan Manbhar Haldhar et al., 2023).

FINDINGS
Upon analysing the various sources of recent literature, there is a revelation several key findings:

1. Enhanced Soil Health
Bio fertilizers and composting, which are few of the particular microbial innovations, go a long way where enhancing the soil health is concerned. The striking improvements that are reflected in the soil fertility are brought about by the advent of these technologies. These have proven to be highly rewarding in agricultural yield. Studies done in Punjab and Haryana have shown the productivity associated with bio fertilizers and composting towards improving the soil health.

Findings by Kaur and Pandove (2023) point at many case studies from Punjab and Haryana in which case use of bio fertilizers and composting can be directly linked to significant enhancement in soil and crop health. When farmers used bio fertilizers in the fields of rice and wheat, increased crop yields were observed. This directly contributes to reduction in the need for chemical fertilizers that are not only expensive but degrading for the environment as well. Hence increased nutrient load, enhanced soil structure, boost in plant growth are huge signs of enhanced soil health working as critical tools for sustainable agriculture.

2. Pest Management:
A comprehensive plan of approach towards pest management like the Integrated Pest management (IPM) has been noted. It is a combination of various biological, cultural, physical and chemical instruments which are specifically targeted to achieve and contain tolerable levels of pest population. There are various microbial characters (bacteria, fungi, viruses) that form the core part of IPM.

Important microbial agents used are Bacillus Thuringiensis (Bt), Trichoderma species and are successfully used in ingesting the pests' digestive systems with toxins and eventually die. These also aid in reduction of plant diseases. Many farmers in agricultural states like Punjab and Haryana are reaping benefits by safeguarding their wheat, rice, cotton, sugarcane, maize and other vegetable crops from rot, diseases and wilt. For instance, the research by Dutta et al. (2023) indicate that cotton farming lands nursed with Bacillus Thurngiensis (Bt) witnessed major decrease in harm inflicted on the crop by caterpillars (targeted action). Hence, economic benefits, targeted pest control and sustainable farming have resulted from IPM practices.

3. Crop Productivity:
Microbial Bio-stimulants and Bio-fertilizers encourage supplemented development of roots, shoot length, biomass production, crop yields, great quality produce and hence sustainable agricultural tendencies.

4. Environmental Benefits:
Microbial use with the focus on degradation or breaking down of pollutants, toxic compounds, pesticidal residues has helped in diminishing contamination and encouraging the ecosystem's health. Microbial degradation marvellously works by reducing toxicity, environmental contamination and for an instance breaking down regularly utilised pesticide- cypermethrin into non-threatening elements. Most importantly, since pesticides tend to pass into rivers or streams close by, microbial degradation of the pesticides comes as a tremendous boon making the environment safer for the crops and mankind to thrive.

Economic Opportunities:
Haldhar et al. (2023) explains that managing the continuation of newer beneficial technologies indicate a strong need towards economic benefits too. These microbial technologies are bringing out opportunities that benefit business enterprises and agricultural factions of India. The advancement and sales of bio-fertilizers, bio-stimulants and bio-pesticides create entrepreneurial ventures and future employment opportunities. In case of farmers, increased crop productivity and quality makes way for them to earn better income which further encourages them to prefer microbial products over chemical fertilizers and /or chemical pesticides.

RECOMMENDATIONS:

Education, training and awareness programmes would be very helpful to capitalise on the advantages of the use of microbial products and by-products. These programmes should aim at learning the hands-on utilization of microbial products and Integrated Pest Management Strategies.

Support through **policies by the government** should be extended towards funding for more research in the area of microbial innovations, subsidies to farmers adopting these technologies, training programs. This would effectively promote the employment of microbial products such as bio pesticides and bio fertilizers in sustainable agricultural practices.

With the support from governing bodies, funding for **research and development** will be imperative in coming up with newer and more effective solutions. Academic institutes, business organizations, government outlets should come together and promote the advancement and economic benefits of innovations in microbial technologies.

The **integration of age-old and contemporary farming practices** would help in deriving the maximum benefits from microbial innovations. Bringing together the traditional insights and current biotechnology should help in the sustenance and longevity of our agricultural systems.

Awareness among the public should be generated with respect to the overall benefits of microbial innovations which will help in acquiring and adopting the culture of sustainable agriculture. Societal campaigning and spreading information will help in assurance and building support for sustainable agriculture through microbial methods.

There are **long-term economic benefits** that can be reaped by promoting microbial technologies. Granting a platform to all the microbial-technology based businesses will lead to the increment of economic output in the agricultural sector. Chemical fertilizers and pesticides are prone to price increases due to market fluctuation. Farmers adopting sustainable agricultural practices through the use of microbial products will be **less prone to market fluctuations.**

CONCLUSION
The applications of microbial technologies are far reaching and beneficial for the management of sustainable agriculture. The solutions are favourable for transforming the soil health for the better, better pest management, crop productivity and thus bestow tremendously to India's agricultural wealth and sustainability. That being said, successful application and implementation of these innovative technologies is not possible without support from the government, education among the farmers' groups and continuous research and development in this field. **Further research** must focus on core applications and increasing efficiency of microbial technologies over a longer period of time. **Increasing the scope of the literature** studied could give a broader insight into the progress made over the years with respect to the economic growth of microbial technologies-based businesses and for future research and exploring other industries and SMEs to validate the findings. As increasing number of farmers begin the practice of utilizing microbial technologies, it would make room for **shaping firmer policies** to support a wide range of applications in agriculture. Prospective success in the fields of agriculture, healthcare and ecology depends on the continual research and technical developments in microbial applications.

SUMMARY
Microbial innovations have applicability in diverse fields namely, agriculture, healthcare and environmental regulations. This paper summarises the microbial adaptations and developments made in agriculture in India

during the year 2023 with leading producers of bio-pesticides entailing various methods of mass-production. Categorization and constitution of various biopesticides and biofertilizers are talked about with the scope for entrepreneurs to setup a business model of tremendous growth. The effect of bio-pesticides on crop quality, soil quality and the environment in contrast to the negative impact of chemically manufactured pesticides. Emphasis is laid on the role of microbes in sustainable practices keeping in mind practical solutions to probable issues, discussion on the market growth and policies on bio-fertilizers and bio-pesticides. Effective management, research and development and commercialization of the combined functions will lead to sustainable management in the agricultural sector and safeguarding of the environment.

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