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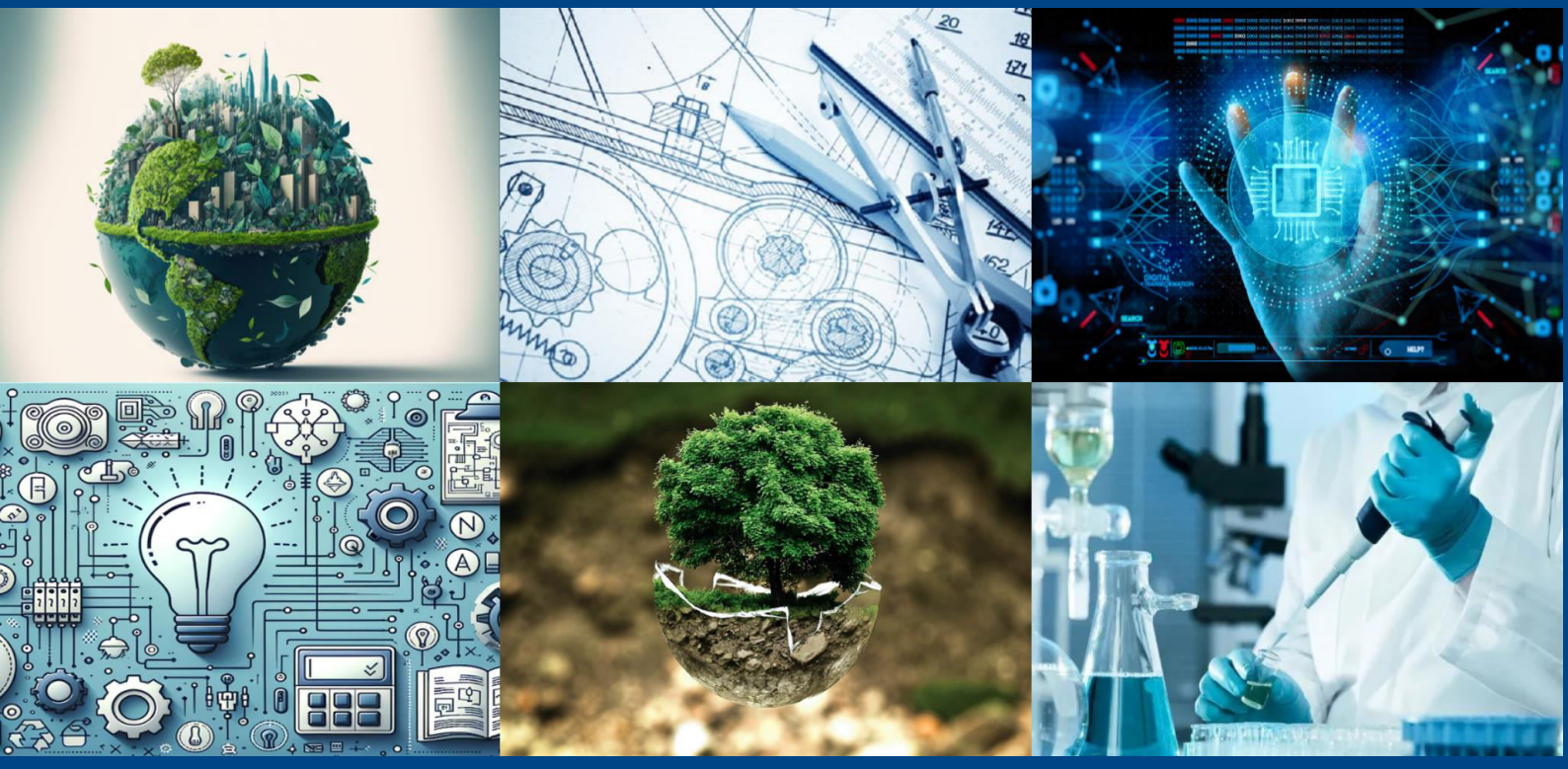

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Nanotechnology in Agriculture Sector for Sustainable Development - An Overview

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ABSTRACT: Agricultural development is a crucial element in the economic development of any nation. One of the primary challenges faced is food scarcity, which is exacerbated by adverse environmental factors. Nanotechnology holds the potential to positively impact the agri-food sector by mitigating negative environmental effects, improving food security and productivity, and promoting social and economic equity. Nanotechnology offers new ways to help farming and build a strong future. This technology can enhance input efficiency and reduce associated losses. However, the production of nanoparticles (NPs) through physical and chemical methods can harm the ecosystem. Consequently, recent decades have seen a shift in nanotechnology research towards green synthesis to accommodate the increasing application of NPs. Utilizing various microorganisms for green synthesis presents a more reliable and sustainable alternative to conventional synthetic methods for producing NPs within biocompatible frameworks. One of the most advantageous applications of the enhanced specific surface area of nanomaterials is in the creation of nanofertilizers. Furthermore, nanoparticles serve as specialized agrochemical carriers, enabling targeted and regulated nutrient deliver while improving crop protection. This review provides updated insights into the diverse applications of NPs for sustainable agricultural development. This overview looks at how tiny tech can aid sustainable growth in agriculture sector. New tools and techniques can make farming better for all.

KEYWORDS: Agricultural Sector, Nanotechnology, nanoparticles, Sustainable Development

I. INTRODUCTION

Nanotechnology plays a significant role in enhancing productivity by managing nutrient levels and also contributes to the monitoring of water quality and pesticides, which is essential for the sustainable development of agriculture. The diverse properties and functions of nanomaterials make it challenging to provide a comprehensive evaluation of their health and environmental risks. The cultivation of various crops and the breeding of livestock are two prevalent practices in agriculture aimed at food provision, significantly contributing to the economic development and prosperity of numerous developing countries. As the global population continues to rise, scientists and engineers are employing innovative methods to boost agricultural productivity. Nevertheless, altering the environmental system for agricultural purposes to satisfy human demands can adversely affect ecosystems. Over recent years, research and application of agricultural nanotechnology have focused on sustainability challenges, crop improvement, and enhanced productivity. Given the rising issues of hunger, under nourishment, and child mortality rates, agricultural nanotechnology holds particular significance in developing countries. The increasing number of publications and patents indicates that both developed and emerging nations, including Germany, Brazil, China, India, France, and Korea, are showing a growing interest in the application of nanoparticles (NPs) in agriculture.

Nanotechnology has the potential to impact the agro-value chain significantly and swiftly, more so, than environmentally friendly technologies and agricultural biotechnology. This technology facilitates synchronized public benefits along with legal, ethical, and environmental advancements. In the near future, nanoscale agrochemicals, such as nanofertilizers and nanopesticides, are expected to become commonplace in agricultural practices globally. The application of nanotechnology in agriculture includes various uses, such as waste water treatment, soil quality

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enhancement, and crop yield improvement through sensors that detect pathogens. Below are several ways in which NPs have contributed.

Objectives of the paper: The paper aims to discuss the role, importance and tries to provide solutions to agricultural sector with the usage of nanotechnology and to promote sustainable agriculture.

- To develop the new applications of nanotechnology in the agriculture sector
- To promote sustainable agriculture with the latest innovations like nanotechnology.

II. THE ROLE AND SIGNIFICANCE OF NANOTECHNOLOGY IN SUSTAINABLE AGRICULTURE:

Pesticides are utilized to manage pests in agriculture. This practice has led to various issues, including harmful effects on humans, pollinating insects, and animals, as well as the contamination of waterways and soils, which adversely affects ecosystems. Nanoscale compounds may provide a potential solution to these challenges. The use of nanoparticles (NPs) in the production of insecticides and chemical fertilizers can help mitigate environmental pollution. Examples of nanomaterials (NMs) that can be readily produced and used as carriers for pesticides or medicines include polymers and NPs. One of the primary factors hindering agricultural productivity is disease; however, applying pesticides post-disease outbreaks can lead to decreased yields. Nanotechnology presents innovative delivery systems and agrochemical agents that can enhance crop productivity while minimizing pesticide usage.

The Advantages of Nanotechnology in improving Agriculture output are outlined below: The emergence of nanotechnology has led to remarkable progress in agricultural methods, providing solutions to some of the most urgent issues confronting this industry today.

a. **Advanced food packaging:** Nanotechnology can be harnessed to produce innovative food packaging materials that offer superior protection against spoilage, prolong shelf life, and incorporate sensors for monitoring food quality, which helps reduce food waste and enhances food safety.
b. **Enhances nutrient absorption:** Nanotechnology facilitates the creation of nanofertilizers that improve nutrient absorption in plants while decreasing nutrient leaching, resulting in higher crop yields and a lesser environmental footprint.
c. **Advancements in plant breeding:** Nanotechnology can be utilizes to advance plant breeding methods, allowing for the creation of new plant varieties with improved characteristics such as greater resistance to diseases, pests, and environmental challenges.
d. **Targeted application of agrochemicals:** Nanotechnology allows for the precise application of pesticides, herbicides, and other agrochemicals, which reduces the quantity of chemicals required and lessens their potential effects on non-target organisms and the ecosystem.
e. **Tolerance to drought and salinity:** Nanotechnology can be employed to create plants that are tolerant to drought and salinity by improving their capacity to withstand water stress, thus boosting crop production in difficult conditions.
f. **Precision farming:** In precision farming, nanosensors and nanodevices can assess soil conditions, crop health, and environmental variables in real-time, enabling more informed decision-making and optimized agricultural methods.
g. **Soil clean-up:** Nanomaterials can be employed for the clean-up of contaminated soils by adsorbing, degrading, or immobilizing pollutants, thereby enhancing soil quality and promoting the sustainable use of agricultural land.
h. **Management of diseases and pests:** Nanomaterials can be utilized for the precise delivery of antimicrobial and antifungal substances, thereby enhancing the management of crop diseases and pests.

III. CHALLENGES AND FUTURE PERSPECTIVES OF NANOTECHNOLOGY IN AGRICULTURE:

Despite the many benefits associated with the use of nanotechnology in agriculture, there are several challenges that need to be overcome for its effective implementation and broader acceptance. These challenges can be generally classified into environmental, health and ethical issues, as well as practical concerns regarding the application of nanotechnology.

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a. **Sustainable Agriculture issues:** Drought-like circumstances are caused by global warming, which poses a significant threat to sustainable agriculture. Drought represents a primary abiotic stressor that restricts the growth, quality, and yield of majority of field crops, such as wheat, globally, jeopardizing the world's food security. It has been well-established that drought stress can disrupt several essential physiological and metabolic processes that are involved in the regulating plant growth and development.
b. **Environmental challenges:** Nanoparticles (NPs) have the potential to pollute soil, water, and air, resulting in negative environmental consequences. The long-term impacts of NPs on ecosystems and their ability to accumulate within the food chain remain inadequately understood. Additional research is necessary to ascertain the fate, transport, and potential environmental hazards of NPs in various agricultural contexts.
c. **Health issues:** The safety of NPs for human consumption is a significant concern that necessitates further exploration. The potential toxic effects of NPs on human health, especially when ingested through food, must be thoroughly investigated to guarantee that agricultural products utilizing nanotechnology are safe for human consumption. Furthermore, the possible occupational risks for farm workers who handle nanomaterials should be assessed.
d. **Ethical Concerns:** The use of nanotechnology in agriculture prompts ethical dilemmas regarding the employment of genetically modified organisms and the potential disruption of traditional farming methods. The possible social and economic repercussions of nanotechnology on small-scale farmers and local communities must be taken into account to ensure that the advantages of this technology are fairly distributed.
e. **Regulatory and Standardization Challenges:** It is crucial to develop suitable regulations and standards for the application of Nanotechnology in agriculture to ensure safety and the foster consumer trust. Regulatory agencies must create guidelines for the testing, labelling and marketing of nanotechnology-based agricultural products to guarantee transparency and accountability within the industry.
f. **Scalability and commercialization:** Developing efficient scalable techniques for the production and application of nanomaterials in agriculture continuous to pose a significant challenge. Furthermore, ensuring that nanomaterials are compatible with current agricultural practices and infrastructure is essential for their effective implementation.
g. **Advancement of nanomaterials development:** The design and synthesis of new nanomaterials with superior properties for agricultural use, such as improved biodegradability, lower toxicity and heightened target specificity will play a pivotal role.
h. **Adopting One Health strategy:** Given the intricate relationships between environmental, Animal and human health, it is crucial to adopt a One Health approach to evaluate the risks and benefits of nanotechnology in agriculture. This comprehensive viewpoint will provide a deeper understanding of the potential effects of nanotechnology on agricultural system and human health.

IV. CONCLUSION

It is preferable to employ green manufacturing methods for the synthesis of NPs to promote environmentally friendly sustainable development. Nanotechnology contributes to agricultural advancement by improving plan growth regulators, increasing nutrient availability, and facilitating the distribution of pesticide active components to targeted areas within plants. Additionally, it reduces the detrimental effects to soil and the agricultural ecosystem. Further investigation is required to enhance the development and application of synthesized nanoparticles in sustainable agriculture, as well as to address their issues. The imperative to nourish the growing global population while minimizing environmental impact is leading to an increased focus on sustainability in agricultural development. The development of climate-resilient crops, the implementation of regenerative agricultural practices, and the use of nanotechnology such as nanofertilizers, nanoparticles and nanomaterials. Furthermore, the use of biofertilizers, organic pest methods, and vertical urban farming are becoming more popular.

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REFERENCES

1. Mukhopadhyay, S.S., 2014. Nanotechnology in agriculture: prospects and constraints. Nanotechnol. Sci. Appl. 7, 63–71.
2. Food and Agriculture Organization of the United Nations The state of food and agriculture, Rome: FAO. https://www.fao.org/3/ca6030en/ca6030en.pdf (2020)
3. A. Gogos, K. Knauer, T.D. Bucheli., Nanomaterials in plant protection and fertilization: current state, foreseen applications, and research priorities J. Agric. Food Chem., 60 (39) (2012), pp. 9781-9792
4. R. Prasad, A. Bhattacharyya, Q.D. Nguyen., Nanotechnology in sustainable agriculture: recent developments, challenges, and perspectives Front. Microbiol, (8) (2017), p. 1014
5. R.K. Sastry, H.B. Rashmi, N.H. Rao., Nanotechnology for enhancing food security in India, Food Pol., 36 (3) (2011), pp. 391-400
6. Lombi, E., Donner, E., Dusinska, M., Wickson, F., 2019. A One Health approach to managing the applications and implications of nanotechnologies in agriculture. Nat. Nanotechnol. 14 (6), 523–531.
7. I. Iavicoli, V. Leso, D.H. Beezhold, A.A. Shvedova., Nanotechnology in agriculture: opportunities, toxicological implications, and occupational risks, Toxicol. Appl. Pharmacol., 329 (2017), pp. 96-111
8. Vijayakumar, M.D.; Vijayakumar, M.D.; Surendhar, G.J.; Surendhar, G.J.; Natrayan, L.; Natrayan, L.; Patil, P.P.; Patil, P.P.; Ram, P.M.B.; Ram, P.M.B.; et al. Evolution and Recent Scenario of Nanotechnology in Agriculture and Food Industries. J. Nanomater. 2022, pp1–17.
9. E.A. Worrall, A. Hamid, K.T. Mody, N. Mitter, H.R. Pappu., Nanotechnology for Plant Disease Management. Agronomy., 8 (12) (2018), p. 285,
10. J.S. Duhan, R. Kumar, N. Kumar, P. Kaur, K. Nehra, S. Duhan., Nanotechnology: the new perspective in precision agriculture., Biotechnology Reports, 15 (2017), pp.11-23
11. N. Basavegowda, K.H. Baek., Current and future perspectives on the use of nanofertilizers for sustainable agriculture: the case of phosphorus nanofertilizer, 3 Biotech, 11 (7) (2021), p. 357

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