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# 8. Biostimulant and Biopesticide Potential in Agriculture

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***Abstract:***

*Crop losses due to various pathogens, including bacteria, fungi, insects, and weeds, pose a significant threat to agricultural productivity, causing economic losses for nations. The historical reliance on chemical fertilizers, pesticides, and other aids, particularly during the green revolution, played a pivotal role in enhancing agricultural production. However, the adverse effects of chemically synthesized inputs became apparent as residues accumulated in soil, water, and crops, negatively impacting the environment and human health. The global demand for safe, non-toxic, and nutritious food products has shifted the focus toward sustainable agricultural practices. The detrimental impact of chemical residues has led to the exploration of alternatives that prioritize food safety and environmental health. Traditional chemical pesticides are now being reconsidered, given their direct and indirect implications on human health and the environment. This paradigm shift is driven by the need for organic and pesticide-independent food ingredients, emphasizing the importance of innovative and safer alternatives for agriculture. In response to these challenges, the agricultural sector is increasingly turning to biopesticides and biostimulants as groundbreaking innovations in agricultural science. Biopesticides, formulated with microbes or plant extracts, not only control targeted harmful pests but also promote the growth of beneficial microorganisms. Compounds like pyrethrin, neem extracts, essential oils, and alkaloids extracted from various plants exhibit significant effects on pests, including repellency, feeding deterrence, and growth inhibition. The application of biopesticides and natural biodegradable nanopesticides emerges as a key strategy for achieving chemical-free agricultural practices in the future. As the world grapples with rising food demands due to population growth and climate change, the necessity for modifying modern agriculture becomes evident. Sustainable cropping practices are crucial for food security and climate resilience. Biostimulants have emerged as a cutting-edge and long-term strategy for crop development, addressing both biotic and abiotic challenges. These substances, with bioactive qualities, can enhance nutrient efficiency, stress tolerance, end-product quality, and nutrient availability in the soil. The identified types of biostimulants include microbial biomolecules, protein hydrolysates, amino acids, humic and fulvic acids, biopolymers, seaweed extracts, and inorganic* *compounds, all commercially available with numerous applications in agriculture. The utilization of biostimulants has demonstrated higher yields even under resource-poor conditions, such as low water availability and degraded lands. Additionally, the use of humic substances in biostimulants contributes to improved soil health by enhancing microbial activity. The adoption of biostimulants and biopesticides not only aids in sustainable agricultural practices but also helps mitigate soil and environmental pollution by reducing the dependence on agrochemicals. The combined potential of biostimulants and biopesticides presents a transformative path towards a more resilient, environmentally friendly, and productive agriculture.*

***Keywords:***

*Bio-stimulant, bio-pesticide, agriculture, environment, health.*

## 8.1 Introduction:

The exploding population of the world has currently crossed the mark of 7.7 billion and is still growing at a flying scale (Roser *et al.* 2020; Kumar *et al*. 2017b). Therefore, this has created a need for an increase in the production so as to meet the food requirement for all. According to the United Nation Prospectus (2011), the world population will rise and get to 10.12 billion in the last era of the century, if the same trends continue (Meena *et al*. 2016, 2017). The actual state questions the current rate of agricultural production. It demands superior, progressive, and more productive agricultural resources to meet up the future requisites.

The innovators and beneficiaries have devoted a significant fraction of their time and energy to meet up these demands looking for the solutions to surfeit the production as well as to perk up the quality of the produce. Before the Green Revolution, production figures were not as satisfying as there was not enough food production to satisfy needs of every individual at all levels (Meena *et al.* 2018a).

The Green Revolution is biggest of the initial milestones in the field of agricultural science as the agricultural production over the map marked an exponential growth. The success of the same was because of the novel methods, techniques, and agricultural aids which were introduced.

The lack of nutritional contents, pesticide attacks, weeds, and other plants fostering the nutritional bout had a decisive role in determining the agricultural produce and still tend to do so. The introduction of chemical pesticides and other insecticides helped the farmers and cultivators to cut the damage done by these external agents. These chemically originated insecticides and pesticides were successfully regulating control over the damage.

The fertilizers were helpful to plants in meeting their nutritional requisites. The pesticides which include insecticides, rodenticides, herbicides, fungicides, and many others were crucial in resolving the rampage as these kept the insects and other microbes competing for plants and animals in control so that their presence does not affect the yield. Moreover, because of the same, the agricultural produce marked a booming production (Oerke 2006).

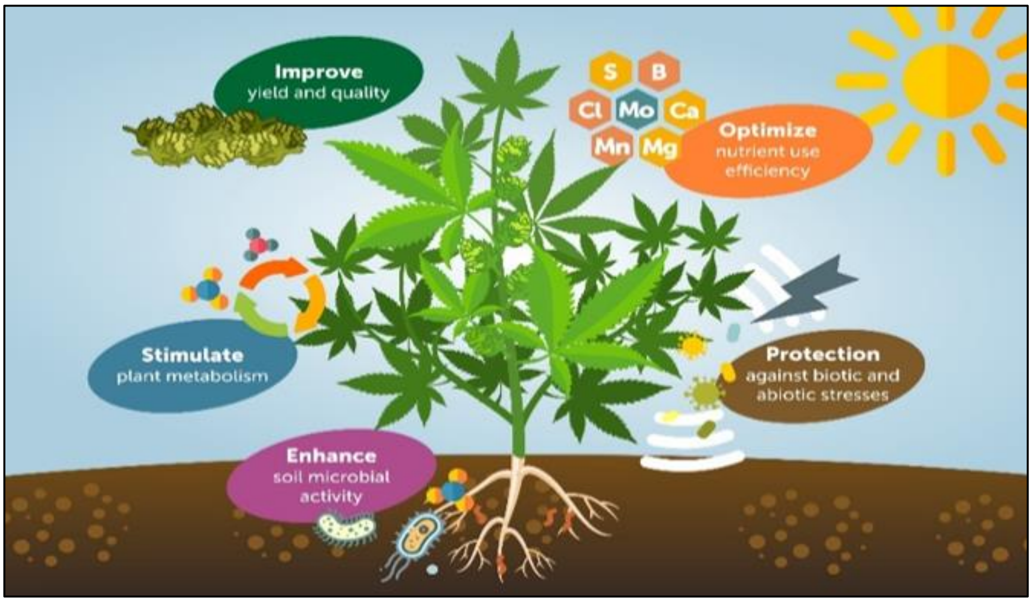


**Figure 8.1: Biostimulants Work**

Firstly, biostimulants were defined by making a distinction between biostimulants and two other often utilised classes of compounds *viz*., fertilizers and pesticides, *i.e.,* defining biostimulants by what they are not. Latterly, it was discovered that bacteria and fungi can likewise provide the beneficial effects attributed to synthetic biochemical stimulants (of synthetic and natural origin), increasing stress tolerance, modulating development and quality attributes, and promoting growth. For instance, PGPRs, known as "plant growth promoting rhizobacteria," are defined by their favourable impacts on plants rather than by their role as fertilisers, insecticides, or soil-improving agents. Their nature can be as varied as chemical substances, and the group PGPR is established based agricultural and horticulture results.

The hard work and dedication of the innovators and scientists all over the globe paved the way by introducing bio-pesticides in the scenario. The bio-pesticides are the pest management tools which were introduced with the sole motive of control on insects and pests without harming the environment, which includes the soil as well as the water profile of the native place. The environment has direct and indirect implications on human and other life-forms residing and inhabiting the place or for the ones who are consuming the produce that is obtained via usage of chemically originated pesticides (Wani and Lee 1995). Bio-pesticides after a bunch of scientific explorations came in light as the substitutes for the chemically synthesized pesticides. Bio-pesticides are synthesized with the help of microbes, plant extracts, and other biologically active principles. Bio-pesticides are one of the gifts of the innovators and biotechnology, and articulated configurations of key constituents rely on micro-organisms like virus, bacteria, fungi or few naturally occurring and industrially prepared substances like plant extracts, semiochemicals, and secondary metabolites. Besides all this, bio-pesticides include organisms which terminate the agricultural pests. There are various types of bio-pesticides based on the constituents that regulate various but specific properties and can be framed in numerous products (Knowles 2006).

**Figure 8.2: The Bio-Pesticides**

## 8.2 Classification of Biostimulants:

### A. Based on Composition:

**Humic Substances**: Derived from decayed organic matter, such as humic acid, fulvic acid, and humin.

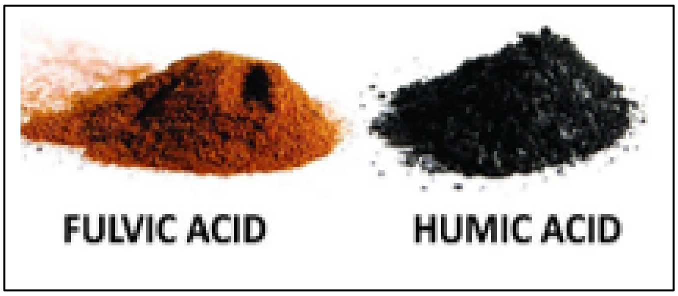


**Figure 8.3: Components of Biostimulants**

**Seaweed Extracts:** Obtained from various types of seaweed and rich in plant growth-promoting substances.

**Amino Acids:** Organic compounds that serve as building blocks for proteins and have a role in plant development.

**Microbial Biostimulants**: Beneficial microorganisms like bacteria and fungi that enhance nutrient availability and promote plant growth.

**Plant Extracts:** Extracts from plants containing growth-promoting compounds.

**Vitamins and Enzymes**: Substances that play a role in various metabolic processes.

### B. Based on Mode of Action:

**Nutrient Uptake Enhancers:** Substances that improve the availability and uptake of nutrients by plant roots.

**Stress Alleviators:** Biostimulants that help plants cope with abiotic stresses, such as drought, salinity, or extreme temperatures.

**Plant Growth Regulators:** Compounds that regulate various physiological processes in plants, such as auxins, cytokinins, and gibberellins.

**Beneficial Microorganisms:** Microbial biostimulants that establish beneficial relationships with plants, such as mycorrhizal fungi or plant growth-promoting bacteria.

### C. Based on Origin:

**Natural Biostimulants:** Derived from natural sources such as plants, animals, or minerals.

**Synthetic Biostimulants:** Chemically synthesized substances designed to enhance plant growth and development.

### D. Based on Application Timing:

**Pre-Plant Biostimulants:** Applied before planting to enhance seed germination and early plant growth.

**Post-Plant Biostimulants:** Applied during the growing season to support plant development, flowering, and fruiting.

### E. Based on Formulation:

**Liquid Biostimulants:** Formulated as liquid solutions or suspensions.

**Solid Biostimulants:** Formulated as powders, granules, or other solid forms.

### F. Based on Functionality:

**Primary Biostimulants:** Directly influence plant growth and development.

**Secondary Biostimulants:** Indirectly influence plant growth by promoting beneficial microbial activity or improving nutrient availability.

## 8.3 Classification of Bio-Pesticides:

Bio-pesticides are principally classified into three broad categories on the ground of critical methods *viz*., (1) bio-chemical (insect sex hormones), (2) phyto-inserted protectants (botanical pesticides like neem oil, rotenone, tobacco suspension, etc.), and (3) plant assisted pesticide-agrocin extracted from *Metarhiziumanisopliae* and *Trichoderma* (USEPA 2008).

### A. Microbial Biopesticides:

**Bacteria:** Examples include *Bacillus thuringiensis* (Bt), which is effective against certain insect pests.

**Figure 8.4: Microbial Biopesticides**

**Fungi:** Species like *Beauveria bassiana* and *Metarhizium anisopliae* are used for controlling insect pests.

**Viruses:** Certain viruses, such as nucleopolyhedroviruses (NPVs), are used to control specific insect pests.

### B. Biochemical Biopesticides:

**Plant Extracts:** Compounds extracted from plants, such as neem oil, pyrethrins, and rotenone, have pesticidal properties.

**Insect Pheromones:** Chemicals that disrupt the mating behavior of insects and are used for insect pest control.

## 8.4 Role of Biostimulants in Agriculture:

Biostimulants play a crucial role in agriculture by promoting plant growth, enhancing nutrient uptake, and improving stress tolerance. These products are designed to stimulate natural processes within plants and the surrounding soil to improve overall crop performance. Here are the key roles of biostimulants in agriculture:

A. **Improved Nutrient Uptake:** Biostimulants can enhance the absorption and assimilation of nutrients by plant roots. They may improve the efficiency of nutrient uptake from the soil, making essential elements more readily available to the plant.
B. **Enhanced Plant Growth and Development:** Biostimulants contain various compounds, such as amino acids, hormones, and vitamins, that stimulate plant growth. They can influence cell division, elongation, and differentiation, resulting in increased biomass and better crop development.


**Figure 8.5: Enhanced Plant Growth and Development**

C. **Increased Stress Tolerance:** Biostimulants help plants cope with environmental stresses such as drought, salinity, extreme temperatures, and other adverse conditions. They may activate stress response mechanisms within plants, making them more resilient to challenging environments.
D. **Promotion of Root Development:** Biostimulants can enhance root growth and architecture. A well-developed root system allows plants to access water and nutrients more effectively, contributing to overall plant health and productivity.
E. **Improved Flowering and Fruit Set:** Biostimulants may positively influence flowering and fruiting processes. They can enhance the development of reproductive structures, leading to increased flower formation, fruit set, and ultimately, higher yields.
F. **Activation of Beneficial Microorganisms:** Some biostimulants foster the activity of beneficial microorganisms in the rhizosphere, such as mycorrhizal fungi and nitrogen-fixing bacteria. These microorganisms contribute to nutrient cycling and availability, further supporting plant growth.
G. **Balanced Hormonal Regulation:** Biostimulants can influence plant hormone balance, including auxins, cytokinins, and gibberellins. This regulation contributes to proper plant growth, flowering, and fruit development.
H. **Reduced Environmental Impact:** Using biostimulants in agriculture aligns with sustainable and environmentally friendly practices. They often have low environmental impact and contribute to reducing the reliance on synthetic fertilizers and pesticides.
I. **Compatibility with Integrated Pest Management (IPM):** Biostimulants are compatible with integrated pest management strategies. They can enhance the plant's natural resistance to pests and diseases, contributing to a more holistic and sustainable approach to pest control.
J. **Adaptation to Climate Change:** In the face of climate change, where unpredictable weather patterns and extreme conditions are becoming more common, biostimulants can help crops adapt and perform better under varying environmental stressors.
K. **Economic Benefits:** Improved crop yields, quality, and stress resistance can lead to economic benefits for farmers. Biostimulants offer a cost-effective and sustainable solution to enhance crop productivity.

## 8.5 Role of Biopesticides in Agriculture:

Biopesticides play a crucial role in sustainable agriculture by providing effective pest management solutions while minimizing the negative environmental and health impacts associated with traditional chemical pesticides. Here are the key roles of biopesticides in agriculture:

A. **Target-Specific Pest Control:** Biopesticides often exhibit a high degree of specificity, targeting specific pests while minimizing harm to beneficial organisms. This targeted approach helps preserve natural predators and pollinators, maintaining a more balanced ecosystem.

**Figure 8.6: Target-Specific Pest Control**

B. **Reduced Environmental Impact:** Biopesticides typically have lower environmental persistence and toxicity compared to synthetic chemical pesticides. This reduces the risk of contaminating soil, water, and non-target organisms, contributing to overall environmental conservation.
C. **Resistance Management:** The use of biopesticides can help manage resistance development in pest populations. Because they often have multiple modes of action, pests are less likely to develop resistance compared to chemical pesticides with a single mode of action.
D. **Integration with Biological Control:** Biopesticides can be integrated into biological control strategies. They complement the activity of natural enemies, such as predators and parasitoids, contributing to a more comprehensive and sustainable approach to pest management.
E. **Safety for Humans and Animals**: Biopesticides are generally considered safer for humans, animals, and beneficial insects. They often have low toxicity levels, reducing the risk of adverse effects on human health and the environment.

**Figure 8.7: Safety for Humans and Animals**

F. **Compatibility with Organic Farming:** Many biopesticides are approved for use in organic farming systems. Their natural origin and environmentally friendly characteristics make them suitable for organic production, meeting the requirements of organic certification standards.

**Figure 8.8: Compatibility with Organic Farming**

G. **Low Residue Levels:** Biopesticides often leave lower residues on crops compared to synthetic pesticides. This is particularly important for crops intended for export or markets with strict residue regulations.
H. **Support for Integrated Pest Management (IPM):** Biopesticides are integral components of IPM programs. They can be used in conjunction with cultural practices, monitoring, and other control methods to create a more holistic and sustainable pest management strategy.

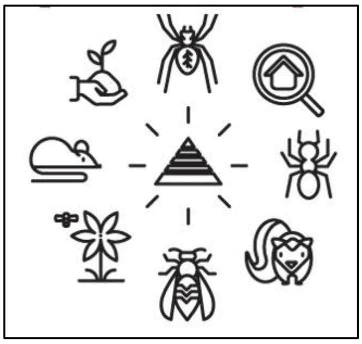

**Figure 8.9: Support for Integrated Pest Management (IPM**

I. **Enhanced Crop Quality:** Biopesticides can contribute to improved crop quality by minimizing the use of chemical residues. This is especially significant for crops that are sensitive to pesticide residues and for markets demanding high-quality produce.
J. **Diverse Range of Products:** Biopesticides encompass a wide range of products, including microbial pesticides (e.g., bacteria, fungi, viruses), biochemical pesticides (e.g., plant extracts, pheromones), and genetically modified crops with built-in pest resistance. This diversity provides farmers with various tools for pest control.
K. **Global Regulatory Support:** Many countries have established regulatory frameworks for biopesticides, recognizing their importance in sustainable agriculture. Regulatory support facilitates the development, registration, and adoption of biopesticides on a global scale.

## 8.6 Opportunities for Biostimulants and Biopesticides in Agriculture:

A. **Growing Demand for Sustainable Agriculture:** Increasing awareness of environmental concerns and the demand for sustainable agricultural practices present a significant opportunity for biostimulants and biopesticides. These products align with the principles of sustainable farming and can contribute to reduced environmental impact.

**Figure 8.10: Growing Demand for Sustainable Agriculture**

B. **Regulatory Support and Certification Programs:** Many governments are recognizing the benefits of biostimulants and biopesticides and are providing regulatory support. Certification programs for organic and sustainable farming further drive the adoption of these products, creating market opportunities for manufacturers.
C. **Consumer Preference for Residue-Free Produce:** Consumers are increasingly seeking pesticide-free and residue-free produce. Biostimulants and biopesticides, with their low residue levels and environmentally friendly nature, cater to this consumer demand, creating market opportunities for farmers and producers.

**Figure 8.11: Consumer Preference for Residue-Free Produce**

D. **Advancements in Biotechnology and Microbiology:** Ongoing research and advancements in biotechnology and microbiology are leading to the development of more effective and targeted biostimulants and biopesticides. Innovations in formulations, delivery systems, and active ingredients enhance the efficacy of these products.
E. **Integration into Precision Agriculture:** Biostimulants and biopesticides can be integrated into precision agriculture practices, allowing for more targeted and efficient application. This integration aligns with the broader trend of using technology for optimized farm management.
F. **Climate Change Adaptation:** As climate change poses challenges to traditional agricultural practices, biostimulants and biopesticides can help crops adapt to changing conditions. These products contribute to climate-resilient agriculture by enhancing stress tolerance and improving overall crop health.

**Figure 8.12: Climate Change Adaptation**

G. **Partnerships and Collaborations:** Collaborations between research institutions, agribusinesses, and technology companies can drive innovation in the biostimulant and biopesticide sector. Partnerships can facilitate the development of new products, technologies, and sustainable farming practices.
H. **Market Expansion in Developing Countries:** As awareness of sustainable agriculture grows, there is potential for the expansion of biostimulant and biopesticide markets in developing countries. These products can offer cost-effective and environmentally friendly solutions to farmers in these regions.

## 8.7 Challenges for Biostimulants and Biopesticides in Agriculture:

A. **Limited Awareness and Education:** A lack of awareness and understanding about the benefits and proper use of biostimulants and biopesticides among farmers can hinder their adoption. Educational initiatives are needed to promote awareness and build trust in these products.

B. **Complex Regulatory Landscape:** The regulatory framework for biostimulants and biopesticides can be complex and varies between countries. Streamlining regulations and providing clear guidelines can facilitate market access for these products.
C. **Efficacy and Consistency:** Ensuring the consistent efficacy of biostimulants and biopesticides across different environmental conditions and crops can be challenging. Research and development efforts are required to improve product reliability and performance.
D. **Market Fragmentation:** The biostimulant and biopesticide market is often fragmented, with numerous small and medium-sized enterprises. Consolidation and standardized approaches may be needed to address fragmentation and enhance market competitiveness.
E. **Cost Considerations:** Some biostimulants and biopesticides may have higher upfront costs compared to conventional synthetic inputs. Convincing farmers of the long-term economic benefits and return on investment is crucial for widespread adoption.
F. **Limited Crop Range and Spectrum:** Some biopesticides may have a limited spectrum of activity, affecting only certain pests or diseases. Expanding the range of target pests and crops can enhance the appeal of these products to a broader audience.
G. **Technological Barriers:** Adoption of biostimulants and biopesticides may be hindered by technological barriers, such as limitations in formulation technologies, delivery systems, and application methods. Ongoing research and development are needed to address these challenges.
H. **Market Competition with Conventional Chemicals:** Biostimulants and biopesticides face competition with traditional chemical inputs that have established market dominance. Demonstrating the efficacy and economic viability of bio-based alternatives is crucial for overcoming this challenge.

**Table 8.1: Impact of biostimulants on crop productions, particularly their cellular targets in plants, whole-plant physiological activities, agricultural/horticultural functions, and eventually predicted economic and environmental benefits.**

| | **Humic acids** | **Seaweed extract** | **Protein hydrolysate** |
|---|---|---|---|
| **Cellular mechanism** (*i.e.* interaction with cellular components and processes) | Activate plasm a membrane proton pumping ATPases, promote cell wall loosening and cell elongation in rootS | Genes encoding micronutrient transporters are activated by *Ascophyllum nodosum* extracts (e.g., Cu, Fe, Zn) | Under salt stress, enzymatic hydrolysate from alfalfa (*Medicaco sativa*) boosts phenylalanine ammonia-lyase (PAL) enzyme and gene expression, as well as flavonoid synthesis. |
| **Physiological function** (*i.e.*, behaviour on whole-plant processes) | Augmented linear growth of roots, root biomass | Up in tissue concern tractions and root to shoot transport of micronutrients | Protection by flavonoids against UV and oxidative damage |

| | **Humic acids** | **Seaweed extract** | **Protein hydrolysate** |
|---|---|---|---|
| **Agricultural/horticultural function** (*i.e.*, output traits pertinent for crop performance) | Expanded root foraging capacity, enhanced nutrient use efficiency | Bettered mineral composition of plant tissues | Augmented crop tolerance to abiotic (*e.g.*, salt) stress |
| **Economic and environmental benefits** (*i.e*. process of making different in yield, products quality, ecosystem services) | More crop output, less usage of fertilizer, and less damage to the environment. | Making better in nutritional value, 'biofortification' of plant tissues (rise in contents of S, Fe, Zn, Mg, Cu) | Up in crop yield under stress conditions (*e.g*., high salinity) |

**Table 8.2: Microbial biocontrol agents (present in bio-pesticides) of various plant pathogens**

| **Bio-agent against pathogens** | **Crop** | **Pathogen** |
|---|---|---|
| *Trichoderma viride, T. harzianum* | Cowpea (*Vigna unguiculata*) | *Macrophomina phaseolina* |
| *Pseudomonas fluorescens* (F113) | --- | *Pythium* spp. |
| *Bacillus cereus* | --- | *Phytophthora medicaginis* |
| *Trichoderma viride* | Pigeon pea (*Cajanus cajan*) | *Fusarium udum* |
| *T. viride, T. virens* | Ginger (*Zingiber officinale*) | *Pythium, Rhizoctonia solani* |
| *T. Harzianum* | Cardamom (*Elettaria cardamomum*) | *Phytophthora* |
| *T. Koningii* | Wheat (*Triticum aestivum*) | *Ustilago segetum* var. *tritici* |
| *Trichoderma spp.* | Mulberry (*Morusalba*) | *Cercospora moricola* |
| *T. viride, T. harzianum* | Rose (*Rosa* spp.) | *Botrytis cinereal* |

## 8.8 Conclusion:

In conclusion, the integration of biostimulants and biopesticides in agricultural practices emerges as a pivotal strategy in addressing the pressing challenges of deteriorating soil health, ensuring long-term sustainability, and mitigating the contributions of traditional agricultural methods to global warming. The application of biostimulants not only enhances the physical, chemical, and biological properties of the soil but also contributes to carbon sequestration. Moreover, the adoption of biopesticides promotes biodiversity in both agro- and natural ecosystems. By incorporating biostimulants and biopesticides into agricultural systems, we establish a foundation for sustainable production while optimizing the efficient utilization of natural resources. When coupled with other sound agricultural practices like the use of high-quality seeds and integrated pest, nutrient, and water management, biostimulants and biopesticides play a crucial role in creating resilient and environmentally friendly farming systems. Furthermore, the innovative application of these bio-based solutions holds promise for ushering in beneficial changes and sustainable stability in crop plants. The deployment of biostimulants contributes to increased water efficiency and improved water-holding capacity of the soil. Biopesticides, by reducing the need for chemical pesticides, not only minimize the environmental impact but also potentially decrease barren land ratios in agricultural areas. As we progress towards a chemical-free agricultural landscape, the use of bio-pesticides and natural nano-pesticides is anticipated to become a prime tool, particularly in the context of sustainable agricultural practices in India and beyond. This holistic approach underscores the dual benefits of enhancing agricultural productivity and preserving the ecological balance, marking a significant stride towards a more sustainable and resilient future for agriculture.

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