Innovative Application of Organic Chemical Molecules in Effective Plant Nutrients

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Abstract. The rampant utilization of chemical fertilizers has precipitated a myriad of adverse environmental repercussions, encompassing phenomena such as eutrophication, soil nutrient depletion, and the percolation of hormones into aquatic ecosystems. In a bid to attenuate the environmental ramifications while preserving crop yield, the amalgamation of chemical fertilizers and organic manure has been advocated by numerous nations, fostering research into the optimal ratio of these fertilizer variants. This study endeavors to delineate the efficacy of organic compounds in fostering growth in various plant components, including the rhizome and fruit. It meticulously examines the impact of these organic entities during distinct plant growth phases, elucidating the reasons behind their diminished environmental detriment and their potential to confer positive effects on adjacent terrains. These benefits are manifested through the mitigation of water loss, curtailment of soil erosion, and the facilitation of nutrient cycling within the agricultural landscape. Looking ahead, the research underscores the promising future of employing organic chemical molecules in agriculture, emphasizing the potential for more precise nutrient segregation to cater to the diverse requirements across various plant growth stages. This approach heralds a paradigm shift towards more sustainable and environmentally benign agricultural practices, steering us towards a future where agriculture harmonizes with, rather than exploits, our precious ecosystems.

Keywords: Organic chemical molecules, crop fertilizer, green resources, plant nutrients.

1. Introduction

Based on today's high requirements of food. Production efficiency is an essential factor to improve during the process of agriculture. At the same time, food safety has become a hot topic today, and people tend to choose more organic foods, such as organic vegetables that are not ripened with chemicals, in order to eat healthier. At this time, in order to avoid reducing production and achieving a higher safety rating of the food. The use of organic chemical molecules to promote crop yield has become a new research direction. Moreover, organic fertilizers can effectively prevent water eutrophication caused by nutrient loss and reduce the pollution of existing fertilizers to the environment) Improving the quality and effectiveness of organic chemicals used in fertilizer, which helps in both the production rate and growth frequency of plants, can be an effective way to improve the production of plants and guarantee food safety, which meets the public requirement in agriculture for both ethical and realistic aspects. This research is going to find out the proper method of using organic molecules in fertilizer to decrease agricultural erosion and promote crop production more organically.

There are specific organic molecules for promoting rhizome growth of plants, for example, auxins, cytokinins and gibberellins. Thus, it is essential for organic fertilizer to contain the ideal potential of elements like nitrogen to supply plants to synthesize organic molecules for root growth. Organic fertilizer is usually made from livestock waste up, silt, decayed branches and leaves, which is produced by decay and fermentation or some bacteria. Fertilizers with different ingredients affect the different growing stages of plants or parts of plants. For rhizome, the specific kind of bacterial manure work and help to promote growth as well as protect the root from getting disease [1]. The bacteria extracted from turmeric help in increasing the plant rhizome quality and quantity in a significant difference from those plants that are not growing in the soil with rhizobacteria and endophytic bacteria. The Auxins and cytokinins are hormones synthesized within plants using nitrogen compounds as the precursor. Thus, fertilizers such as manure, compost and Alfalfa Meal can work as good resources that continue releasing nitrogen compounds such as Ammonium nitrogen, nitrate nitrogen and urea nitrogen.

2. Growth Promoter

2.1. Increased Resistance to Adversity

The design of hormone mimicants of organic molecules has three main factors: chemical structure, stability and specificity. The hormone designed is required to be similar in structure to the plant hormone it tries to mimic. The less difference between hormone mimicants and plant hormones, the higher the possibility for them to interact with the same receptor and enzymes within the plant. Thus, they can help promote plant growth just like how plant hormone works. The second factor for fertilizer to be effective is to make sure the hormone mimicants is stable enough that they will not denature in working condition, such as in soil or when added to plants. The main mechanism used to maintain the stability of hormone mimicants is to conduct stable chemical structures and isotopes that help contain the structure of molecules under different situations. Specificity is also one factor that should be considered when designing hormone mimicants. Research finds that some nematodes conducted hormonal cross-talk to specific plant development pathways to set up sites for food [2]. By using hormones and controlling the growth of plants, nematodes succeeded, promoting the growth of plants in the aimed area.

The mechanism of action of hormone mimicants consists of four parts. Receptor binding, signal transduction, specific responses and dose quantity. For receptor binding, the hormone mimicants only affect when it is able to bind to the same receptor on plant cells and then trigger the growth of the plant. Signal transduction works when hormone mimicants bind to receptors. The mimicant initiates signal transduction pathways within the plant cell. This can lead to a cascade of biochemical reactions that regulate gene expression, cell division, elongation or other growth processes. The specific response of the hormone mimicant depends on the type of mimicants used. Specific growth responses can be included. Take auxin mimicants as an example; they may promote root growth and branching, while gibberellin mimicants may stimulate stem elongation and flowering. For dose-dependent mimicants the effectiveness of hormone mimicants is often dose-dependent. Different concentration of mimicants can lead to varying growth responses, and excessive application have a negative effect on both plant and the surrounding environment.

2.2. Enhancing the Stress Tolerance of Plants and Coping with Environmental Stresses

The organic molecules help plants in different ways to enhance the stress tolerance of plants and help plant crops with environmental stresses. Organic molecules such as polyphenols, flavonoids and vitamins can act as antioxidants [3]. They help plants combat oxidative stress caused by factors like drought, extreme temperature or pollution by neutralizing harmful free radicals. The organic molecules support the microbial population, which benefits soil nutrition to plants. These microbes contribute to nutrient cycling, improve soil structure, and enhance a plant's ability to absorb water and nutrients, ultimately helping plants better cope with stress. Organic molecules can also influence the production and balance of plant hormones. For instance, the presence of organic materials can promote the synthesis of stress-responsive hormones like abscisic acid (ABA), which helps plants manage water stress. As mentioned before, Organic matter improves soil structure and encourages root development. The bacteria help prevent diseases. Well-developed root systems can help plants access water and nutrients even in challenging conditions.

In addition, Organic-rich soils have better water-holding capacity, reducing the impact of drought stress. Organic matter acts like a sponge, retaining moisture in the soil for longer periods. Some organic compounds can induce systemic acquired resistance (SAR) in plants, making them more resistant to diseases and pathogens, which are often exacerbated under stressful conditions. Organic molecules can be used in the form of biopesticides and bio-fungicides derived from plant extracts or beneficial microorganisms [4]. Several kinds of microorganisms, such as Bacillus, Candida, Lactobacillus and Streptomyces, have been found to show positive effects in the fight against fungi. These can help protect plants from pest and disease stress.

3. Molecular Design and Synthesis

3.1. Optimized Activity and Stability

For the design of organic molecules, several factors need to be met. The needs, growth hormones, and stress tolerance of plants should be detected in the first place. For example, ethylene can promote plant ripening of fruit [3]. Plants that grow for cultivating fruit will require organic chemical molecules such as ethylene included in the molecular design. The function of molecules to help in enhancing the process of nutrition absorption is an important design direction. Organic chelators can bind essential minerals and make them more available for plants to absorb. The organic acids help plants in mineral gaining and tolerance to toxic minerals [5]. The fertilizer should be biofertilizer, which contains beneficial microorganism-friendly molecules that can improve soil health, thus benefiting the nutrient cycling of the field. It has been found that field use of Trichoderma-enriched bio-fertilizer showed a positive result on improved levels of soil microflora and soil fertility frequency [4]. After the design, the process of synthesis of molecules should also be eco-friendly by not releasing harmful chemicals byproduct. Finally, the field testing of organic molecules is required to predict and minimize the following possible effects on the environment. This process can also find out the organic chemical efficacy.

3.2. Ensuring Molecule's Effectiveness in the Plant Environment

Aiming to ensure the effectiveness of organic molecules in plant environments. The essential step is to figure out how to optimize the activity and stability of molecules. To achieve this goal, there are several factors required to achieve. The structural modification of molecules, by altering the molecule's structure to enhance its activity. This can involve adding functional groups, changing the stereochemistry, or modifying the backbone. Bioavailability can improve the molecule's solubility and ability to penetrate plant tissues. Formulate it as a nanoscale delivery system or use surfactants to enhance dispersion. Molecules' stability will protect the molecule from degradation due to environmental factors like UV radiation, temperature, or pH fluctuations. Encapsulate it in protective coatings or use stabilizing additives. Dose Optimization of organic molecules determines the optimal concentration for application to avoid toxicity while ensuring efficacy. This often requires dose-response studies. Delivery Systems of organic chemicals develop specialized delivery systems such as microencapsulation or slow-release formulations to extend the molecule's activity over time.

Synergistic Combinations help in combining molecules with complementary modes of action to enhance overall effectiveness. Synergistic combinations can improve pest resistance or nutrient uptake. Residue Management of molecules makes them break down quickly and safely in plant tissues or soil. Organic chemicals targeted Create molecules that respond to specific triggers (e.g., environmental cues or plant signals) for controlled release in response to plant needs. The biological compatibility of molecules ensures their compatibility with beneficial microorganisms in the soil and rhizosphere to maintain a healthy ecosystem. Environmental Impact Assessment is essential to conduct before popularizing the organic fertilizer. Evaluate the ecological impact of the molecule to ensure it does not harm non-target organisms or disrupt ecosystems.

4. Reducing the Negative Effects of Chemicals on Farmland

4.1. Reducing the Use of Chemical Fertilizers by Organic Manure

Organic molecules can be designed as biopesticides that specifically target pests while sparing beneficial organisms. These natural or synthetic compounds are less harmful to the environment than chemical pesticides. Genetic modification can introduce organic molecules into crops, making them inherently resistant to pests and reducing the need for external pesticides. Organic molecules can be part of IPM (Integrated Pest Management) strategies, where they are used in combination with cultural, biological, and physical pest control methods to minimize pesticide use. Organic molecules can enhance the effectiveness of biological control agents, such as predatory insects or nematodes, by providing a more favorable environment for these natural predators. Nutrient Efficiency Enhancers: Molecules like organic chelators or slow-release fertilizers can improve nutrient uptake efficiency in plants, reducing the need for excessive fertilizer application. Organic molecules can be used to enhance soil microbial activity, which in turn improves nutrient availability and reduces the reliance on synthetic fertilizers.

Stress Tolerance Inducers: Molecules that enhance a plant's stress tolerance can reduce the need for chemical treatments in response to environmental stresses, like drought or disease. Organic molecules can be designed to be biodegradable, minimizing their persistence in the environment and reducing the risk of soil or water contamination. Utilizing organic molecules in precision agriculture allows for targeted and controlled application, reducing overuse and wastage of pesticides and fertilizers. Many countries have regulations to encourage the use of environmentally friendly products in agriculture. Organic molecules that meet these standards can be favored over traditional chemicals. By reducing pesticide and fertilizer use, organic molecules help preserve non-target organisms and maintain a healthier agricultural ecosystem. Reduced Runoff: Using organic molecules that improve nutrient retention in the soil can reduce nutrient runoff into water bodies, preventing water pollution.

4.2. Organic Chemicals’ Promotion of Soil Health and Ecological Balance

The organic molecules also improve the soil quality and ecological surroundings in diverse ways. Improved Nutrient Retention of organic molecules. Organic molecules, such as humic and fulvic acids, can chelate essential nutrients like iron, calcium, and magnesium, making them more available to plants. This enhances nutrient retention in the soil and reduces leaching, which can otherwise lead to groundwater contamination. Conducting Microbial Activity Enhancement, organic molecules serve as a food source for beneficial soil microorganisms. This encourages the growth of a diverse microbial community, including mycorrhizal fungi and nitrogen-fixing bacteria, which support nutrient cycling and soil structure improvement. Organic molecules contribute to the buildup of soil organic matter. There is a method suggesting cumulating the organic matter in the field through intensive grazing [6]. The cumulation of organic matter improves soil structure, water-holding capacity, and aeration, enhancing the overall health of the soil.

Certain organic molecules can act as pH buffers, helping to maintain optimal soil pH levels for plant growth. This is crucial because extreme pH levels can limit nutrient availability. The research shows that by using biochar, it successfully absorbs the toxicity of phenol [7]. Organic matter, aided by organic molecules, helps bind soil particles together, reducing erosion caused by wind and water. This protects against soil loss and maintains the integrity of the ecosystem. The experiment showed that 30% of organic molecules prevent the loss of about 72% of soil [8].

Organic molecules can improve the soil's water-holding capacity, reducing the need for frequent irrigation. This helps conserve water resources and promotes sustainable water use. Sticky rice in food waste manure helps slow and stop the water loss from soil [9]. By promoting healthy plant growth and strong root systems, organic molecules contribute to stabilizing soil, preventing erosion and the loss of fertile topsoil. Some organic molecules have antimicrobial properties, which can help suppress soil-borne pathogens, reducing the need for chemical treatments and promoting ecological balance. Organic molecules aid in the breakdown of organic matter, facilitating the release of nutrients from decaying plant and animal material. This nutrient-recycling process enriches the soil. Several types of organic matter support the biodiversity of the area of the field. Healthy soil ecosystems supported by organic molecules provide habitat and sustenance for a wide range of soil organisms, from earthworms to insects and small mammals [10]. This fosters biodiversity and ecological balance. The use of organic molecules aligns with sustainable farming practices, reducing the reliance on synthetic fertilizers and chemicals that can harm the environment and disrupt ecological balance. The use of microorganisms, such as bacteria, fungi and cyanobacteria, plays the same role as harmful chemical fertilizer [11]. Long-Term Soil Fertility: Organic molecules contribute to the development of long-term soil fertility, ensuring that agricultural land remains productive for generations to come.

5. Challenges and Prospects

5.1. Technical Challenges

Technical and Synthetic Problems people currently meet on using organic molecules as fertilizer are mainly shown below. Organic molecules must protect nutrients from degradation due to environmental factors or chemical reactions. Researchers need to design stable carriers for nutrients. Creating organic molecules that release nutrients gradually to match plant needs is a complex task. Achieving the right balance between slow release and nutrient availability remains a challenge. Organic molecules must target specific nutrients and deliver them effectively. Achieving nutrient specificity for different crops and soil types is an ongoing challenge. Developing organic molecules that respond to environmental cues, like soil pH or root exudates, to release nutrients on demand is a promising direction but requires advanced technology. Designing user-friendly formulations for organic molecules, such as granules or coatings, without compromising nutrient release efficiency remains a synthetic challenge. Balancing biodegradability with stability is essential. Future developments may focus on materials that degrade at specific stages in a plant's growth cycle. Scaling up production while maintaining quality and consistency is crucial. Innovations in manufacturing and process optimization are needed. Reducing production costs without compromising nutrient efficiency is a key goal for future developments. Meeting evolving regulatory standards and conducting thorough safety and efficacy assessments is essential for product approval and acceptance. Developing strategies to prevent resistance in plants or soil organisms to organic nutrient molecules is critical for long-term effectiveness.

There are also some future directions for the development of organic chemical fertilizers. Nanotechnology can enhance nutrient delivery and release. Future research may explore nanoencapsulation and nanoscale delivery systems. Biotechnology genetic engineering of plants to interact more efficiently with organic nutrient molecules could lead to crops that are better adapted to these inputs. Smart Delivery Systems, which can Incorporate sensors or responsive materials into organic nutrient products, can enable real-time nutrient release adjustments based on plant and soil conditions. Machine Learning on organic chemicals enables Data-driven approaches, and machine learning can help optimize nutrient formulations and predict crop-specific requirements. Biostimulants that focus on developing organic molecules that stimulate plant growth and nutrient uptake can complement traditional fertilizers, reducing the overall nutrient load. Circular Agriculture that may occur in the future and its developments may focus on closed-loop systems that recycle organic waste materials into nutrient-rich products. This study field will help in reducing waste and promoting sustainability. Sustainable Sourcing, which is exploring environmentally friendly sources for organic molecules, such as renewable biomass or waste streams, can align with sustainability goals. Microbiome Management, by understanding and harnessing the plant-soil microbiome, can lead to innovative solutions for nutrient delivery and plant health. Addressing global agricultural challenges may require international collaboration to share knowledge and resources. The researcher also requires awareness and training on innovative organic nutrient technologies that can facilitate their adoption in agriculture.

5.2. Future Direction of Designing Organic Molecules

Precision Agriculture Integration. The integration of organic molecules into precision agriculture systems will become more widespread. This will enable real-time monitoring and precise application of nutrients based on plant and soil conditions. Organic molecules tailored to help plants withstand climate-related stresses, such as drought, heat, or increased salinity, will be a priority to address the challenges of changing environmental conditions. Regulatory Frameworks done by Governments and regulatory bodies will establish clearer guidelines for organic nutrient products, ensuring their safety and effectiveness while supporting innovation in the field. Multifunctional Nutrients to meet more requirements. Organic molecules will be designed to serve multiple functions simultaneously, such as nutrient delivery, pest resistance, and soil improvement, reducing the need for separate input.

6. Conclusion

There are diverse kinds of organic chemicals promoting plants in different stages and parts. This research discussed the poor aspects of both organic and chemical fertilizers that have effects on the environment and the growth of plants. Based on the previous relevant researcher, combining the use of two kinds of fertilizer can be the most effective way to achieve a proper use of fertilizer. In order to design the proper organic matters for plant promotion. The organic molecules should be considered in effectiveness, specificity, least pollution and extracting difficulty. It is also important to consider the use of chemical fertilizers because of their slow release rate.

The research list several programs for using different quantity of each kind of manure. Nevertheless, low numbers of them meet all the requirements that agriculture needs nowadays. There are still diverse difficulties that have to be overcome. For example, the effective use of organic molecules on different parts of plants instead of only on rhizome systems. The low rate of organic manure can cause low efficiency in promoting growth. The organic matter, which is hard to extract from organisms or raw materials, also makes the cost of fertilizer rise significantly. After extracting the organic chemicals, the preservation and methods used to maintain the high quality of organic matter can also be an aspect that agricultural scientists had to spend time developing. In the future, this organic manure may be used as the majority fertilizer based on the development of both using and extracting organic chemical molecules.

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