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Review Article

Nanochemistry: A Multidisplinary Approach towards Innovations in Agriculture Soils and Improved Yields

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Abstract

Agriculture has made significant strides recently, and sustainability build on those successes by using a smart strategy that may maintain greater returns and farm profitability without depleting the resources. Furthermore, nano-materials enhance the efficiency of farm production to enable site targeted regulated distribution of minerals, assuring the least amount of agri-input usage while enhancing crop output. Particularly in the agriculture industry, nanoscienceis crucial for agricultural production, food packaging and processing, water purification, nutrition security, and pollution control as well as crop development and plant preservation. NPs display a well-organized antibacterial activity towards bacteria and viruses. Important inorganic NPs with effective pesticide characteristics include silver, aluminum and copper. Chitosan nano-particles, ZnO nano-particles, and silica nano-particles are beneficial for the treatment of virus infection, including the mosaic virus in tobacco, potatoes, and alfalfa. The revitalization of the damaged soil resources may be possible using nano-enabled soil rehabilitation. The toxicity copper in soil is typically linked to soluble free metal ion species like Cu2+, that are easily accessible and extremely hazardous, in traditional forms of higher soil.

Keywords: Agriculture industry, nano-technology, pollution control, crop output.

INTRODUCTION

The use of fertilizers helps to increase agriculture productivity, but excessive fertilizer use permanently changes the chemical ecosystem functions of the soil, minimizing the area that can be used for agricultural production. A minimal use of agrochemicals is required for sustainable farming in order to safeguard the natural environment and prevent the annihilation of numerous organisms [1-3]. Furthermore, nano-materials enhance the efficiency of farm production to enable site targeted regulated distribution of minerals, assuring the least amount of agri-input usage while enhancing crop output. In fact, the use of nanomaterials in plant protection solutions has grown tremendously, which could guarantee higher crop output [4, 5].

Nanotechnology, one of the many scientific breakthroughs, has been named as a viable technology for revitalizing the food and agriculture business and improving the standard of living for underprivileged. Nanoscience has enormous potential applications in a number of industries, including health care, minerals, textiles, technology for information and communication, and energy [6-8]. Particularly in the agriculture industry, nanoscienceis crucial for agricultural production, food packaging and processing, water purification, nutrition security, and pollution control as well as crop development and plant preservation. The use of site specific medication and gene delivery of substances at the molecular and cellular levels in livestock and plants, as well as genetically modified of animals and plants using nano-arrays under stress, can all increase agricultural production. With the help of nano-technology, resistance to disease, plant development, and mineral nutrition could all be improved. Nano encapsulating products demonstrate the potential for more resource and greener site specific applications of insecticides, pesticides, and herbicides. It is effectively employed in post-harvest to preserve the quality, freshness, and storage stability of stored goods as well as to avoid disease outbreaks in a relatively safer manner [9-12].

In addition, the main issue with crop output is how to speed up plant adaptability to the effects of global warming, such as harsh weather, salinity, water scarcity, alkalinity, and damage to the environment with toxicants, without endangering already fragile ecosystems. Many nano-particles, including Cu and Ni ferrite nano-particles, have significant anti-fungal properties and are utilized to manage diseases. Chitosan nano-particles, ZnO nano-particles, and silica nano-particles are beneficial for the treatment of virus infection, including the mosaic virus in tobacco, potatoes, and alfalfa [1, 6, 9].

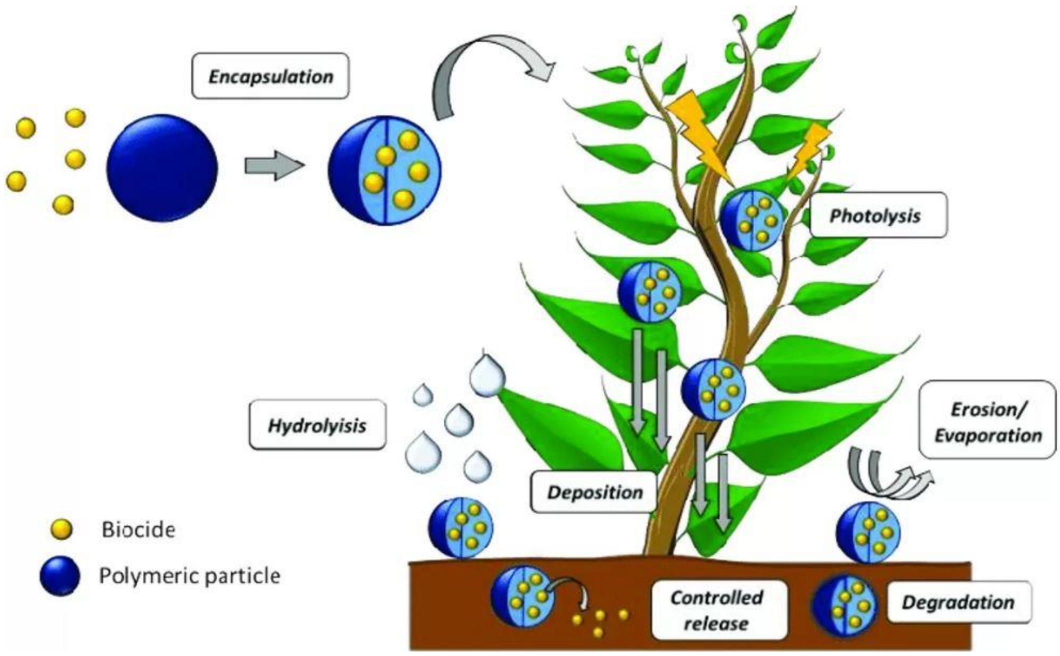

Fig-1: Nanoscienceand its Potential appliactions

Nanoscience and its Multidisciplinary appliactions

According to research on hydrogels, nano-zeolites and nano-clays, soil can hold more water and operate as a slow release reservoir of water, which reduces dry spells during the growth period. Deployment of such solutions are advantageous for restoration of degraded regions as well as for smart agriculture. Nano-materials, both organic (e.g., polymers and carbon nano-tubes) and inorganic (for example, nano-metals and metallic oxides), have also been applied to absorb environmental toxins, improving soil restoration capacity and lowering treatment durations and expenditures [12-15].

By improving nutrient absorption and use of elements, carbon nano-tubes and nano-particles of SiO_2, TiO_2, ZnO, and Au, can help improve plant growth. Moreover, the vulnerability of the species of plants, the real effect of nano-materials on depends primarily on their concentration, chemical and physical properties, size, composition and surface charge. The creation of novel procedures and the application of various analytical methods (such as micro-scopey, fluorescence spectroscopy and electromagnetic resonance imaging) could significantly advance our understanding of how plants interact with nano-materials [16-18].

Although agricultural fertilisers, particularly, are still not developed by the big chemical corporations, nano-fertilizers have been widely accessible on the market for the past ten years. Nano-fertilizers may include nano-scale amounts of silica, ZnCdSe, iron, titanium dioxide, core shell QDs, ZnS core shell QDs, ZnSe QDs, gold nano-rods and other materials. They should also provide controlled release and enhance their product's quality. For agriculture productivity, extensive research on the absorption, biological destiny, and poisoning of a number of metal oxide nano-particles, including Al_2O_3, CeO_2, ZnONPs, FeO, and TiO_2, has been conducted in the last ten years Given the alkaline character of the soils, a zinc deficit has been identified as one of major issues restricting agricultural output [19, 20].

In order to fulfil the rising need for food, modern agriculture is being used, however this approach eventually creates a vicious cycle where fertility of the soil is depleted and agricultural outputs fall. According to estimates, 40percent of all farm production worldwide has suffered major degradation, which has resulted in a significant soil fertility loss [18, 19]. As a result, massive amounts of fertilizers' are utilized to increase agricultural output and soil quality [20, 21]. Additionally, it has been clearly seen that fertilizers' account for one third of agricultural production, with the remaining two thirds depending on how effectively other agriculture inputs are used. However, the efficiency of traditional fertilizers' in using nutrients rarely exceeds 30–40percent. For instance, throughout the last few decades, the mineral utilization efficacy of traditional fertilizers, such as N 30-35percent, P 18-2percent, and K 35-40%percent has not changed [22-24]. Moreover, the final volume of the fertilizers' that reach the intended sites has a significant impact on how well they absorb nutrients when applied to the soil directly onto leaves.

Sustainability in the perspective of crop improvement refers to the replacement of pesticides and capital with farm grown bio-inputs and expertise, with the goal of reducing production costs without diminishing output. Agriculture has made significant strides recently, and sustainability build on those successes by using a smart strategy that may maintain greater returns and farm profitability without depleting the resources. Based on human objectives and knowledge of long term effects of human activities on the environment and other animals, sustainable agriculture is a reality. This way of thinking blends the use of past knowledge with the most recent scientific discoveries to develop integrated, resource conserving, fair farming systems. The systemic approach reduces environmental deterioration, preserves agricultural output, fosters short and long term financial viability, and upholds life quality [23-26].

In comparison to synthetic nano-pesticides often bind energy and water when they are discharged, although to a lesser extent and less often. Due to higher yields, potentially lower costs, and a reduction in waste and labour expenses, they also increase pesticide effectiveness and crop yields. Additionally, NPs display a well-organized antibacterial activity towards bacteria and viruses. Important inorganic NPs with effective pesticide characteristics include silver, aluminum and copper. Nano-herbicides, which often involve bio-degradable polymeric elements, can boost herbicides' effectiveness. For instance, due to its superior physiochemical characteristics and higher bioavailability and bio - compatibility, poly (-caprolactone) is frequently utilised to contain atrazine. A conveyor belt system that is based on CNTs can be employed to introduce artificial ingredients into hosts after aiming to reduce the amount of chemicals released to the environment which might harm other plant tissues [27-30].

To assure that the agriculture industry is more productive, strong, and viable, agriculture research needs to undergo a revolution, and nanosciencewill be important in developing intelligent crop structures. These intelligent crop systems will aid in addressing the problem of food storage, which is a significant worldwide dilemma [31, 32]. By boosting the number of genetic resources, non-enzymatic chemicals, and enzymes, NPs can successfully transport micro-nutrients or provide protection against insects or pathogens. By lowering cost of production and post-harvest loss with the aid of nano-grams, nano-pesticides, nano-fertilizers, nanosensors, nano-bags, and nano-chips, Nano-materials can also aid in improving crop performance and quality. Through the smart provision of active components and the decrease of nutrient depletion during the fertilization process, Nano-materials will also decrease the quantity of sprayed agro - chemicals and boost their effectiveness [33-37].

Traditional chemical fertilization is not only bad for the environment, but they also have poor nutrient absorption rates, that makes them expensive and unsustainable. When compared to the conventional fertilization, crop plants use nano-particles with a significant surface - to - volume ratio that range in size from 10 to 100 nm far more efficiently. In order to increase fertility of the soil, crop plants' ability to absorb nutrients, and ultimately their production, numerous nanoparticles have been effectively used as macro- and micro-nutrients in ield of nano-nutrition of agricultural crops. Nevertheless, reports on the hazard of these nanoparticles in agricultural crops have also been made [38, 39].

Metallic oxide nan-materials (TiO2, CuO and ZnO), carbon nano-materials (CNTs, graphene oxides, C70), and nZVI are examples of common materials undergoing extensive research. Whereas CuO was observed to be significantly greater toxic than the zi nc oxide in terms of a helpful bacterium, P. chlororaphis O6, zinc oxide was classified as "very toxic" in the perspective that it is capable of infecting 100percent morality of E. coli, P. fluorescens and B. subtilis. The distinctive physical, biological and chemical properties of nano-technology, which differs from those found in a large scale models for the same substance, have drawn the attention of numerous scientists. Nano-materials have a wide range of uses in industries like health, therapeutic agents, electronics, food, solar cells, fuel cells, space exploration, and more. Nano-materials have demonstrated numerous advantages for the treatment of various soil contaminants in these applications. Numerous techniques exist for using nano-materials to assist in the identification and remediation of soil contaminants. Nano-materials maintain solid waste, prevent soil erosion, and precipitating soil contaminants. Although nanosciencehas enormous promise for soil restoration, just a few concerns will be covered in this study [11, 13, 19].

The degradation and pollution of soil continue to be significant environmental problems, and its rehabilitation is an international task. Global soil degradation has a serious negative impact on global food security, agriculture production, and human wellbeing, hence it needs to be addressed right away. The need to produce more food to feed the world's expanding population is driving an increase in the degradation and exploitation of land and soil. This global catastrophe is further exacerbated by the poisoning of soil with toxic substances, herbicides, and persistent organic contaminants. Due to these contaminants' tendency for bio-accumulation, soil that has been contaminated with them increases the danger of food supply chain poisoning [22, 29, 31]. The need to produce more food and difficulty of halting additional soil erosion both severely hamper agriculture output. The revitalization of the damaged soil resources may be possible using nano-enabled soil rehabilitation. Uses based on nanoscienceare inexpensive, easy to apply, and suggest more effective remediation and treatment procedures that could significantly lessen soil contamination.

The useful life, transportation, and destiny of nano-particles have an impact on effectiveness of de-contamination in soil environment. The fate and transit of nanoparticles employed in soil stabilization, unfortunately, are not well understood at this time. Cu was first used in farming in 1882 when a mixture of Bordeaux, a well-known anti-fungal agent made of CuSO4 and Ca(OH)2, was used. Cu based nanoparticles have antibacterial qualities because of their tiny size and ion-releasing capacity. Due to their varied actions against various microorganisms, they can work as a broad spectrum anti-microbial agent to safeguard plants against insects and illnesses. Copper based nanoparticles tiny size makes it easier for plants to absorb them, increasing their biological effectiveness and reducing the risks associated with their overuse and runoff. Lastly, this might lessen the overall negative effects that agriculture has on the agro - ecosystem, especially the soil system [11, 19, 27].

The toxicity copper in soil is typically linked to soluble free metal ion species like Cu2+, that are easily accessible and extremely hazardous, in traditional forms of higher soil. Copper concentrations, that are caused by heavy metal contamination. Copper based nanoparticles, on the other hand, may have special features that include an as-of-yet unidentified mode of danger [35-39].

CONCLUSION

Diverse reactions may be elicited by the bio-transformation of Cu nanoparticles in soil and plants according to the application stage. As a result, toxicity brought on by metals or metallic oxide Copper nanoparticles may produce quite different reactions and levels of toxicity than toxicity brought on by metallic Copper. Furthermore, the toxicity and destiny of copper nanoparticles in soil are significantly influenced by soil geo-chemical parameters as pH, texture, organic matter, and EC. Their homo/hetero aggregation, bio-transformation, bio-availability, and solubility in soil are most likely to be affected by these characteristics.

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