Nanotechnology: A Boon for Agriculture

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Nanotechnology refers to the branch of science and engineering devoted to designing, producing, and using structures, devices, and systems by manipulating atoms and molecules at nanoscale, i.e. having one or more dimensions of the order of 100 nanometres (100 millionth of a millimetre) or less. The nanoparticles with small size to large surface area (1–100 nm) have potential medical, industrial and agricultural applications. Scientists have carried out significant efforts toward the synthesis of nanoparticles by different means, including physical, chemical and biological methods. These methods have many disadvantages due to the difficulty of scale-up of the process, separation and purification of nanoparticles from the micro-emulsion (oil, surfactant, co-surfactant and aqueous phase) and consuming large amount of surfactants. Green methods for synthesizing nanoparticles with plant extracts are advantageous as it is simple, convenient, eco-friendly and require less reaction time. Nanomaterials prepared by eco-friendly and green methods could increase agriculture potential for improving the fertilization process, plant growth regulators and pesticides. In addition, they minimize the amount of harmful chemicals that pollutes the environment. Hence, this technology helps in reducing the environmental pollutants and nanotechnology has recently gained attention due to its wide applications in different fields such as in medicine, environment and agriculture. Particularly, the large surface area offered by the tiny nanoparticles, which have high surface area, makes them attractive to address challenges not met by physical, chemical pesticides and biological control methods.

The word "nano agriculture" refers to the infusion of nanotechnology concepts and principles in agricultural sciences so as to develop processes and products that precisely deliver inputs and promote productivity without associated environmental harm. Indeed, the unique properties of materials at nanoscale make them suitable candidates for the design and development of novel tools in support of a sustainable agriculture (figure 1).

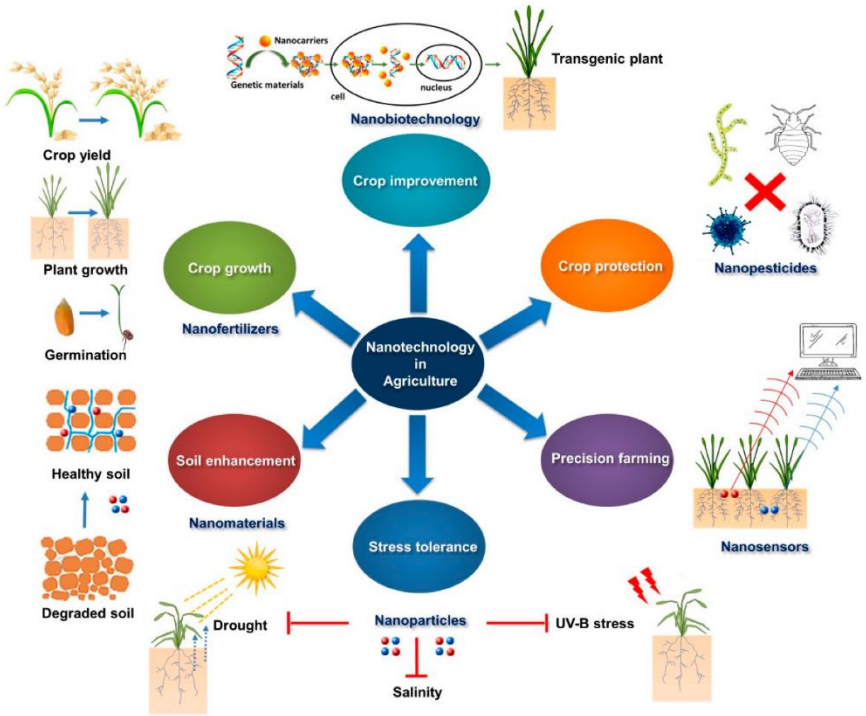

Fig. 1: Applications of nanotechnology in agriculture

The application, as an example, for the development of intelligent nanosystems for the immobilization of nutrients and their release in soil. Such systems have the advantage to minimize leaching, while improving the uptake of nutrients by plants, and to mitigate eutrophication by reducing the transfer of nitrogen to groundwater. Furthermore, it is noteworthy to mention that nanomaterials could also be exploited to improve structure and function of pesticides by increasing solubility, enhancing resistance against hydrolysis and photodecomposition, and/or by providing a more specific and controlled-release toward target organisms. Nanotechnology can increase agricultural production, and its applications include: (1) nano formulations of agrochemicals for applying pesticides and fertilizers for crop improvement; (2) the application of nano sensors in crop protection for the identification of diseases and residues of

agrochemicals; (3) nanodevices for the genetic engineering of plants; (4) plant disease diagnostics; (5) animal health, animal breeding, poultry production; and (6) postharvest management. Precision farming techniques might be used to further improve the crop yields but not damage soil and water. In addition, it can reduce nitrogen loss due to leaching and emissions, and soil microorganisms. Nanotechnology applications include nanoparticle-mediated gene or DNA transfer in plants for the development of insect-resistant varieties, food processing and storage and increased product shelf life. Nanotechnology may increase the development of biomass-to-fuel production. Experts feel that the potential benefits of nanotechnology for agriculture, food, fisheries and aquaculture need to be balanced against concerns for the soil, water and environment and the occupational health of workers. Nanotechnology uses are currently being researched, tested and in some cases already applied in food technology. Nanomaterials are considered with specific chemical, physical and mechanical properties. In recent years, agricultural waste products have attracted attention as source of renewable raw materials to be processed in substitution of several different applications as well as a raw material for nonmaterial production. Insecticide resistance is one of the best examples of evolution occurring on an ecological time scale. The study of insecticide resistance is needed, both because it leads to understanding mechanisms operating in real time and because of its economic importance. It has become in insects an increasing problem for agriculture and public health. Agricultural practices could include wide range of selective regimes. Nanotechnology applications are being tested in food technology and agriculture. The applications of nanomaterials in agriculture aim to reduce spraying of plant protection products and to increase plant yields. Nanotechnology means like nanocapsules, and nanoparticles are examples of uses for the detection and treatment of diseases. Nanotechnology derived devices are also explored in the field of plant breeding and genetic transformation. The potential of nanotechnology in agriculture is large, but a few issues are still to be addressed as the risk assessment. In this respect, some nanoparticle attractants are derived from biopolymers such as proteins and carbohydrates with low effect on human health and the environment. Nanotechnology has many uses in all stages of production, processing, storing, packaging and transport of agricultural products. Nanotechnology will revolutionize agriculture and food industry such as in case of farming techniques, enhancing the ability of plants to absorb nutrients, disease detection and control pests.

Nanomaterials as Agents to Stimulate Plant Growth

Nanotechnology helps to improve agricultural production by increasing the efficiency of inputs and minimizing relevant losses. Nanomaterials are used to control the effective release of the right doses of plant nutrients which makes the fertilizer nutrients more available to the nanoscale plant pores. The application of TiO2 was reported to increase the yield by promoting growth, photosynthetic rate, and by reducing disease severity.

Nanotechnology in crop protection

Some nanomaterials can kill plant pathogenic microorganisms and resist plant viruses. Some nanomaterials can stimulate the immune system of plants. Sensors developed using nanomaterials can be used to monitor plant disease processes. Many nanomaterials, such as ZnO nanoparticles and silver nanoparticles, are available for plant disease control. We provide services for designing, synthesizing, and optimizing nanomaterials for plant disease control, and we offer services to study their disease control mechanisms.

Nanotechnology in plant genetic engineering

Nanomaterials can be made as delivery tools of nucleic acids for plant gene editing. This helps plant protection-related gene editing. We provide services to help develop passive delivery nanomaterials and precisely release controlled nanomaterials to fuel the nanotechnology application in plant editing. And we provide safety assessment services for nano-delivery materials to confirm the safety of using such nanomaterials.

Nanotechnology in stress tolerance

The application of nanoparticles helps the plant survive under stress conditions by aiding in the anatomical adaptations of the plant. The

TiO_2 nanoparticles have been successful in regulating the stomatal opening in maize plants under heat stress, thus reducing its impact.

Nanotechnology in soil improvement

Nanoparticles absorb/adsorb a large variety of contaminants and also catalyze reactions by lowering the energy required to break them down, owing to their unique surface properties. As a result, this remediation process reduces the accumulation of pollutants while limiting their spread from one medium to another.

What is the role of nano biosensors in agriculture?

Nano biosensors can be effectively used for sensing a wide variety of fertilizers, herbicide, pesticide, insecticide, pathogens, moisture, and soil pH. Taken together, proper and controlled use of nano biosensor can support sustainable agriculture for enhancing crop productivity.

Overall, nanotechnology provides creative solutions for the problems encountered by agriculture by increasing precision in monitoring soil conditions and insect infestations, optimising resource utilisation, and minimising environmental effects. Furthermore, nanotechnology can help in the development of crop types that are resilient to stress, allowing farmers to adjust to climate change and guarantee long-term sustainability in food production. The goal of the investigation of nanotechnology in agriculture is to develop farming methods that are more robust, ecologically friendly, and effective.

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