Editorial

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Nanotechnology for agro-environmental sustainability

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New agricultural practices have been developed to improve food production by using more efficient pesticides and fertilizers i.e. current requirement to feed growing world population. These technologies suffer from major drawbacks such as these technologies can lead to the uncontrolled release of unwanted substances into the environment, with potential contamination of soil and groundwater. Excessive use of chemical fertilizers and unsafe chemical pesticides can lead to environmental pollution and serious health problems. Today, nanotechnology is emerging as promising approach for improving agricultural production and remediation of contaminated sites. Nanotechnology is one of the fifth revolutionary technologies of the century after biotechnology. It has shown a wide range of applications in agriculture, biology, chemistry, electronics, materials science, medicine, and physics. Ecological nanoscience products and processes have an impact on the socio-economic aspects of maintaining a clean environment for sustainable development. Nanotechnology is a broad and interdisciplinary field of research and development activities that is growing exponentially worldwide. Nanotechnology will provide the capacity to create affordable products with dramatically improved performance.

Increasing food production using sustainable practices to meet the hunger of a growing population is one of the major challenges in a world. Increased demand for food as a result of global population growth has encouraged the widespread use of fertilizers. Fertilizers though are an inevitable source for improving soil fertility and crop productivity, regardless of the nature of the environmental conditions but are expensive, leads to eutrophication and many health hazards. Further, due to bioresource constraints and low use efficiency of chemical fertilizers, the cost for the farmer is also increasing dramatically. Additionally, the arable lands and water resources limitations leaves the only option for developing the agricultural sector by improving resources use efficiency with the minimum damage to production bed through effective use of modern technologies.

Nanotechnology thus offers a great potential to nano-fertilizers and nano-pesticides production with to improve the nutrient use efficiency, beneficial environmental impact and boost up the plant productivity and protections (Figure 1). It is envisioned that nanoscale science and nanotechnology will be revolutionize agricultural productivity and agro-food systems. The use of nanofertilizers and nanpesticides increases the nutrient use efficiency, enhance soil health/fertility, minimizes adverse effects associated with overdose and reduces the frequency of their applications [1, 2]. Nano-fertilizers are nutrient carriers with nano-dimensions in the range of 30 to 40 nm and able to retain an abundance of nutrient ions due to their large surface area and to release it slowly and evenly in proportion to crop demand. Nano-fertilizers increase the efficiency of metabolic and physiological reactions in the plant thereby increasing the rate of photosynthesis and enhanced the yield of the crops. It prevents plant from different biotic & abiotic stress. Nano-fertilizers are very effective for precise nutrient management for agricultural sustainability, coinciding with the crop growth phase for nutrients and can provide nutrients as per requirement by crop. Nano-fertilizer is fairly innovative, and recent reports strongly support that there is a lot to be done before the technology reaches the farm gate [3].

Indiscriminate use of chemical pesticides led to numerous environmental problems such as resistance and environment pollutions. Nanotechnology is visualized as a rapidly evolving field & research into applications of nanotechnology in agriculture has become increasingly popular over the past decade (Figure 2).

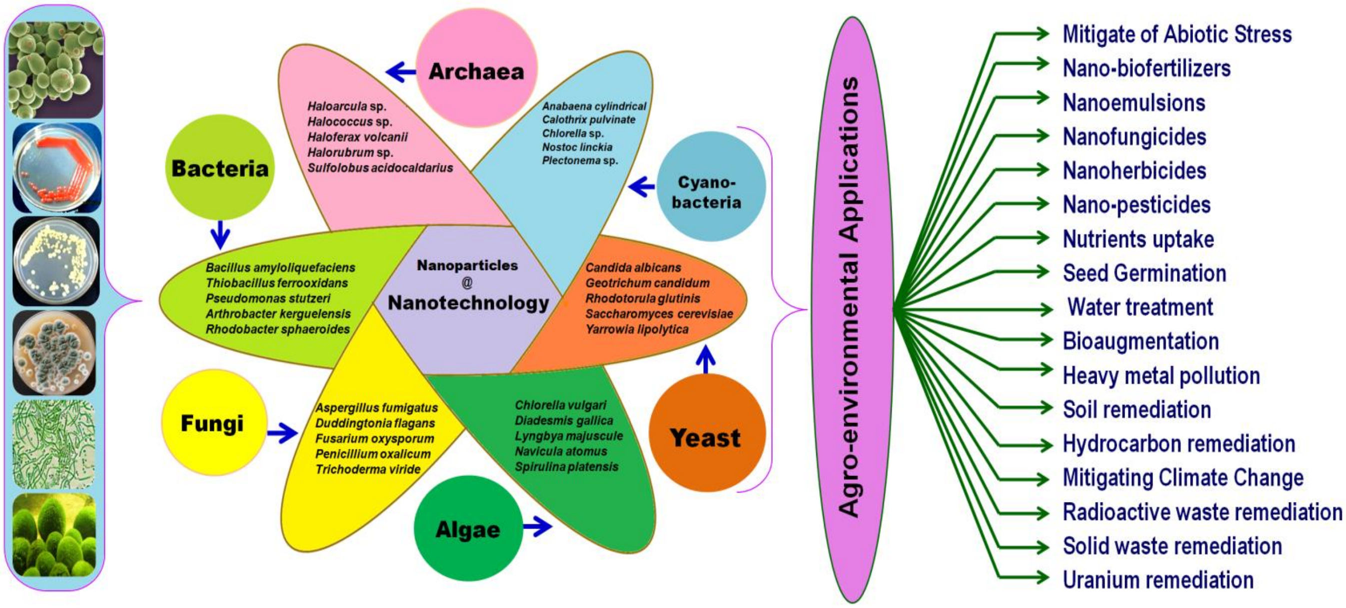

Fig. 1 Microbial nanoparticles and their biotechnological applications for agro-environmental Sustainability.

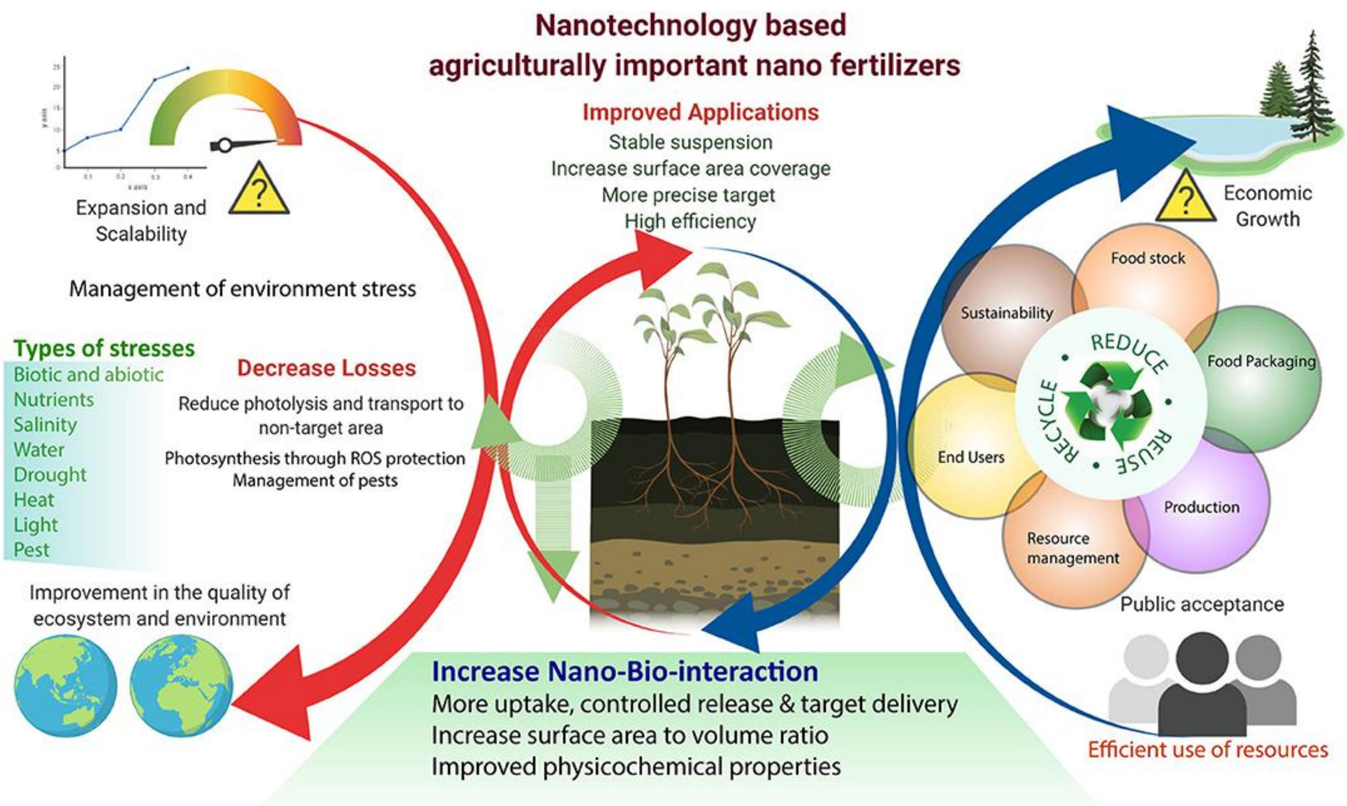

Fig. 2 Nanotechnology-based agriculturally important nano-fertilizers. Source-Adapted from Mittal *et al.* [43]

The development of novel plant-protection products has received greater attention than other applications [4]. Nanopesticides act as pesticide active ingredient or other small engineered structures with beneficial pesticidal properties. Nanopesticides have higher or similar bio-efficacy in pest mortality compared to conventional pesticides. Reports show that nano-pesticides possess the ability to reduce toxic impact of chemical pesticide and provide target specific control of crop pest [5]. Nanopesticides will be useful in minimizing the major problems faced I agricultural sector such as food productivity and security as well as environmental imbalance.

In the twenty-first century, agriculture faces multiple challenges to produce more food by tackling the problems of rapid world population growth, unpredictable climate change, declining agricultural productivity, a changing workforce, and increased urbanization. Nanotechnology has the efficient to strengthen the mission towards the evergreen agriculture by increasing productivity with application of limited uses of inputs. Nanotechnology is widely used in food processing and production; plant productivity and protection, environmental pollutions management [6]. The application of nanotechnology emerges as a paradigm shift and is evolving as a promising tool to usher in a new era of precision farming techniques and can therefore provide a possible solution for improvement of crop, even in challenging environments [7, 8]. Accurate information through applications of nanotechnology for real time monitoring of soil conditions, environmental changes and diseases and plant health issues. The studies have reported increased seed germination, fresh biomass, higher yield in diverse range of crops with application of nanoparticles [9]. Nanomaterials can be used as nanofertilizers for balance crop nutrition, weed management, plant growth regulators, soil management, seed technology, and precision agricultural techniques for promoting increased crop yields without damaging soil and water. Nanotechnology thus has enormous benefits and offers a huge platform by providing sustainable alternatives in the agricultural sector.

In last few years, nanotechnology has been emerged as invaluable technology and gained much attention of the environmentalist for the remediation of pollutants present in water, air as well as soil. Nanotechnology is a science of petite particles for environmental remediation has known to be a low cost, effective and environmental friendly technology [10, 11]. Remediation of environmental pollution mechanism is quite fast as the surface area of the nanomaterials is large due to which decontamination rate increases [12]. Various studies have also been published in which nanomaterials have been known for the remediation of environmental pollutants. In a report, nanoparticle made prepared by immobilizing ethylenediaminetetraacetic acid (EDTA) on the surface of amine terminated Fe_3O_4 (Fe_3O_4–NH_2/PEI-EDTA) and this nanoparticle was used for the remediation of lead. The results have concluded that nanoparticle Fe_3O_4–NH_2/PEI-EDTA significantly altered lead concentration and after treatment with HCl this could be reusable [13]. In another report, nanoparticle of iron oxide was reported for remediating the arsenic metals [14]. In similar report, heavy metals lead and mercury polluted water was reported to be degraded by the ZnS nanoparticle gels [15]. In 2013, a report concluded that chitosan beads supported Fe^0 nanoparticles was an efficient decontaminator of heavy metals like copper, chromium, and lead [16]. In a study, a pot trail was conducted to conclude that nanometer particle size hydroxyapatite was remediating the heavy metals like copper, chromium, lead and zinc [17].

In different nanoparticles of TiO2 and ZnO was reported for the degradation of azo dye, acid red 27 and coralene red F_3BS dyes under the UV light [18]. In a similar report, methyl orange azo dye was reported to be degraded by hollow cobalt nanoparticles [19]. In another report, magnetic adsorptive Fe_3O_4 nanoparticles was reported for the degradation of copper, cobalt, cadmium and nickel [20]. In an investigation, taro plant rhizome powder supported Ag nanoparticles were reported for the remediating pollutants like picric acid, nitrophenols and organic azo dyes [21]. Xenobiotics, pesticides were also reported to be degraded via nanoparticles. In a study, bimetallic nanoparticles of Fe/Ni were reported for efficient remediation of organophosphorus pesticides [22]. In another report, heavy metals were remediated via *Bacillus cereus* based green synthesized silver nanoparticle. This type of nanoparticle was helpful in remediating chromium and lead by 98.43% and 99.4%, respectively [23]. In another report, the combination of zinc oxide nanoparticles and bacteria namely, *Bacillus cereus* and *Lysinibacillus macroides* was tested for the removal of heavy metals like lead and copper stress in plants.

Water is the one of the most precious component of living world. The precious component has now become a one of the pollution spots like soil due to rapid increase in urbanization and industrialization. Water bodies including lakes, rivers and even oceans are polluted with oils, heavy metals, azo dyes, pesticides, waste sludge and other xenobiotics. According to World Health Organization (WHO) the amount of potable water have been decreases and around 1 billion people worldwide have no access to water due which it management become a major issue for society and public authorities. Various methods have been recognized and even applied in the past years for the treatment of water and use of nanomaterials is an emerging technique. Utilization of nanomaterials is more effective and durable than the current available options and various studies is available that have concluded nanomaterial utilization is an effective method [24]. In a report, uranium contaminated water effluent was treated by the zero-valent iron nanoparticles (INP). The study concluded that INP was remediating uranium contaminated water effluent efficiently [25]. In a similar report, INP and magnetite was also reported for remediating uranium affected water [26]. The another investigation, drinking water contaminated with arsenic heavy metal was remediated via using nano-alumina which was dispersed in chitosan-grafted polyacrylamide [27].

Nanoparticle zero-valent iron was also reported in another study for remediating the groundwater. The INP in this study was modified by polyacrylic acid [28].

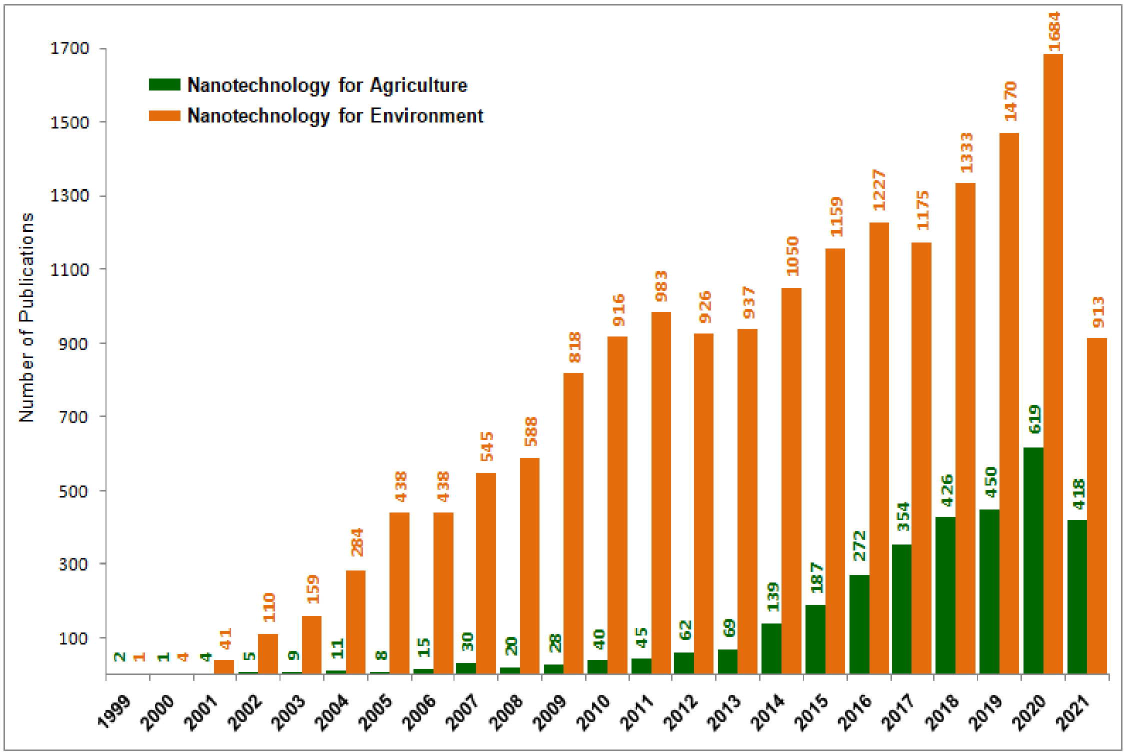

Figure 3 Number of research publications on role of nanotechnology for agro-environmental sustainability [Source-PubMed, Keyword-Nanotechnology for agriculture, Nanotechnology for environment.

In another report, facile immobilized gold nanoparticles were also reported as effective material for water remediation [29]. Zinc oxide nanoparticles photocatalysts was also report in a study for the remediation of water from pharmaceuticals [30]. In different report, contaminated water was also treated efficiently with Si nanoparticles [31]. The lead and copper contaminated water was also reported to be remediated with the help of superparamagnetic maghemite (γ-Fe_2O_3) nanoparticles which was synthesized by flame spray pyrolysis [32]. Heterostructured HfO_2/TiO_2 spherical nanoparticles were reported for remediating the contaminated water [33]. In another report, ecofriendly biometallic silver and iron nanoparticles was also reported for the remediating contaminated water [34]. Similarly, vanadium oxide nanoparticle was reported for remediating water contaminated with methylene blue [35]. In another investigation, zero-valent Sn nanoparticle was reported for remediating water contaminated with lead metal [36].

Nanoparticles, an element which reads in nanometer is said to be occur naturally or produced by humans. They have been used in the fields like agriculture, environment and industries for the purposed like fertilization, production, remediation and production of goods [37]. Nanoparticles used in various fields are broadly classified into two main types i.e. organic and inorganic nanoparticles. Organic nanoparticles included compact polymeric, lipid nanoparticles, dendrimer, hybrid, nanocapsule and nanosphere. Lipid nanoparticles have further types such as micelles, liposome and nanocapsule. Micelles types are the lipid molecule which is arranged spherically because of hydrophobic interactions in an aqueous solution. Whereas, liposomes nanoparticles are spherically shaped vesicles that contain phospholipid layer. They are formed from the natural phospholipid and cholesterol. This type of nanoparticles is mostly used for the drug delivery system [38]. On the other hand nanocapsule is made of phospholipid molecules [39].

Dendrimer is nano-sized, monodisperse, and symmetric molecules. They are branched, multivalent and spherical molecules with artificial elasticity. They are mostly used in drug discharge purposes. Fullerene, the other type of organic nanoparticle comprises of carbon molecules with extremely symmetric and stable. Inflexible icosahedrons (a polyhedron with 20 faces) with 60 carbon atoms (C_{60}) are one the famous fullerene [40]. On the other hand inorganic nanoparticles comprises silver, lead, gold, platinum, copper, iron, fullerene, and quantum dot [41]. Quantum dots are semi-conductor which are also referred as nanometer-sized crystals. They are small device that contains small electrons. The other inorganic types of nanoparticles are mostly have three dimensional structures are used in industries, environment and agriculture [42].

Nanotechnology is now emerging as potent technology in the agriculture and environment sectors. There are huge numbers of finding as nanotechnology for agro-environmental sustainability (Figure 3). Recent studies have begun to address the use of nanoencapsulation of active compounds such as antimicrobials, antioxidants, colorants, drugs, flavors, micronutrients, minerals, probiotic microbes, and vitamins. New preparations of nanoantimicrobial are showing promising effects by protecting food from deterioration thereby extending the shelf life of food. Studies show that the uses of nanomaterials as delivery systems improve the bioavailability of bioactive compounds as nutritional. Worldwide commercial foods and food supplements containing added nanoparticles are becoming available. The use of nanocharcoal adsorbent in decoloration of food products is another important application. Nanotechnology positively influences each sector of food industry including food processing, packaging and quality monitoring of food and its products to ensuring safety and wholeness. Nanotechnology is rapidly moving from the laboratory onto supermarket shelves and kitchen tables with potential to revolutionize food systems. Today, nanotechnology has shown a wide range of applications in agriculture, biology, chemistry, electronics, materials science, medicine, and physics. Nanotechnology is a broad and interdisciplinary field of research and development activities that is growing exponentially worldwide.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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