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Effect of accumulation of nanoparticles in soil health- a concern on future

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Abstract

Nanotechnology proved as a boon to this era and is widely applied in many areas of science and technology. Agriculture is the backbone of industrial raw material and it is very important to have technologies supporting high yield, better crop production and protection in a cost effective, ecofriendly and sustainable way. Globally, there is a lot of research being conducted in the field of application of nanoparticles in agriculture. In recent time nano-based materials like nanoparticles and nanoformulations, nano-based fertilizers, nano-pesticides and insecticides, nano fungicides and other plant disease control formulations are available in the market. Though this technology offers many advantages, yet there are some vices which is causing the concern among the researchers and practitioners. The unregulated exposure of the nanoparticles to the soil is expected to cause adverse effects on the soil microbiota and in some cases negatively impact the important adaphic factors like soil infertility and toxicity. The studies conducted so far have shown diverse responses of nanoparticles by soil fungi and soil bacteria. The enzymatic activities of the microbes have been reported to be affected when the stress is induced from different sources. In some studies, silver nanoparticles have been found to decrease FDA- hydrolysis in soil. More research still needs to be done on addressing the nanoparticle induced metal-stress by different microbes. This review provides the comprehensive account of side effects of the nanoparticles on soil fertility and their effect on the different properties of soil and plant growth along with the research gaps in the field of soil application of nanoparticles and way forward to introduce an ecofriendly application of nanoparticles.

Introduction

Nanotechnology is one of the versatile technologies which find a wide application in material and living world. Nanoparticles have a size of 10-9 which works as an efficient carrier of the targeted molecules to atomic and subatomic levels and facilitate in development of novel things with desirable characteristics. This manipulation of atoms and molecules for design and development of novel products may be either top down which means reducing the size of the smallest structures to the nanoscale e.g. photonics applications in nanoelectronics and nanoengineering or the bottom up which involves manipulating individual atoms and molecules into nanostructures and more closely resembles chemistry or biology (Figure 1).

A nanometer is a billionth of a meter. Overall nano refers to a size scale between 1 nanometer (nm) and 100 nm in at least one dimension and involves developing or modifying materials or devices within that size. To address the challenge of making technology more sustainable, ecofriendly and of precised application, nanotechnology is emerging up as a technology of choice. The research and application of nanotechnology in other sectors is gaining steady momentum, the same in agriculture and tool processing is yet to get in the mainstream research [1]. With the application of nanoparticles enhancing the soil fertility and supporting organic cycles in the soil, the microbial activity is enhanced which helps in addressing the wastelands, infertile lands and toxic landscapes to support vegetation and farming. In the existing croplands, the nanoparticles mediated nanofertilizers support in increasing the fertility and crop growth. Overall, nanotechnology provides the efficiency of the agriculture for a higher population. Since the agriculture sector has a huge responsibility of producing food for the world, the advent of technology and particularly, nanotechnology is probably going to encourage and outline the following phase of advancement of crops, animal farming, pesticides and accuracy cultivating strategies (Figure 2) [2].

Nanotechnology in agriculture

Agriculture farming is the foundation of most developing economies; roughly 60% of the population relies upon horticulture for their work. Indian farming division represents 18% of India's total national output (GDP) and gives work to 50%of the workforce of the nation. Nanotechnology impacts the horticulture efficiency with the assistance of the Nano-fertilizer, Nano-pesticides or Nano-herbicides which act as a smart delivery system to plants, likewise the different industries making definitions with Nanoparticles (100-250 nm) to improve their activities by expanding Nanoparticles solubility in water. The soil is a very important component of the land and it is the mixture of organic matter, minerals, gases, liquid and organism that support the life on the earth.

Soil

Soil well-being has been defined as the limit of soil to work as a living framework, with the environment and land use limits, to continue plant and living system efficiency, keep up or upgrade water and air quality, and advanced plant and living organism's well-being. Solid soils keep up a various network of soil creatures that assistance to control

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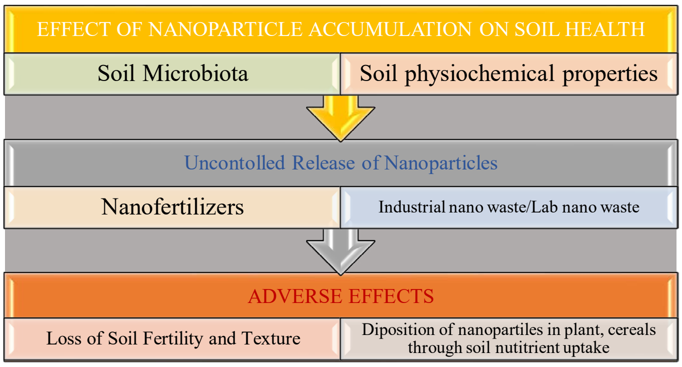

Figure 1. An Overview of Effect of nanoparticles on Soil Health

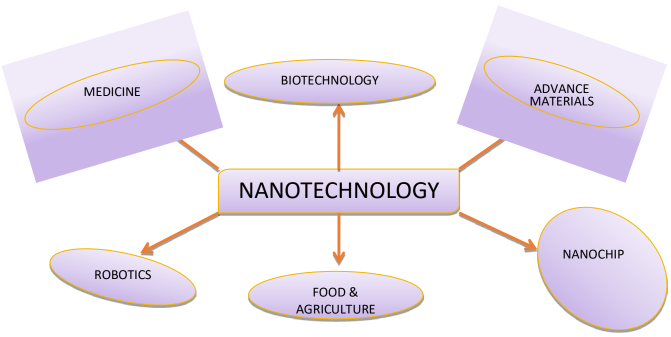

Figure 2. Nanotechnology and its relation with other fields

plant disease, pests, and insects, frame salutary cooperative relationship with plant roots; reuse fundamental plant supplements; enhance soil structure with positive repercussions for soil water and supplement holding limit, and improvement in the yield of crops [3]. There are four important factors i.e. carbon transformations, soil structure maintenance, control of pests and diseases and the nutrients cycle; play a significant role in the soil health. In detail, we can say that all these factors broadly depend upon biochemical process and microbial activities performed by a small microorganism present in the soil.

It is reported that NPs in medicine and biology was valued at US$17.5 billion in 2011 with the further estimate to reach approximately US $53.5 billion in 2017 and US$79.8 billion in 2019 [4]. Silver NPs are estimated to be used up to 4 t per year [5]. Zinc NPs are estimated to be produced up to 5500 t per year replacing their bulk counterparts in a range of products [6].

The studies based upon the modeling and analysis provides a piece of information regarding synthesis, application and unsafe disposal of various nanoparticles in huge amount (several hundred tons) every year. Metallic oxide-based nanoparticles e.g. Ag, Al, C, Ce, Cu, Fe, Si, Ti, Zn are accumulated in the environment in association with soil, sludge, and other wastes. Other natural resources like air and water are mostly contaminated with a significant amount of nanoparticles [7]. The increasing quantity of NPs is expected to prompt high concentration in the environment and potentially a higher risk to the living beings. Residues and deposits in large quantities will expand the likelihood of antagonistic associations between living things and nanoparticles [8]. It is reported that nanoparticles affect microscopic properties of soil, e.g., humic acid content and soil bacterial community [9] nanoparticles once released in the environment have an influence on microbial diversity and can also affect plant growth [10]. As the higher utilization of nanotechnology in numerous applications is increasing, it is raising various issues like ecological, toxicological, agricultural, well-being and security, mechanical, strategy, and administrative aspects. A few uses incorporate deliberate arrival of NPs into nature bringing about expanded quantity and concentration after a long time [11] without intense poisonous quality; bioaccumulation and long term exposure and presentation have unsurprising effects on the evolved way of life, which is unanswered [12].

Types of nanoparticles

Nanoparticles can be arranged into various forms as indicated by the size, morphology, physical and substance properties. Some of them are carbon-based nanoparticles, ceramic nanoparticle, metal nanoparticle, semiconductor based nanoparticle, polymeric nanoparticles and lipid-based nanoparticles. Based on shape, they can be classified into quantum dots, nanotubes, nanofibres, nanorods, nanosheets, aerogel and nanoballs [13] and can also be classified as either magnetic or non-magnetic nanoparticles.

Metallic nanoparticles are silver (Ag), gold (Au), titanium oxide (TiO_2), iron oxide (Fe_2O_3), zinc oxide (ZnO), or copper (Cu). Silver nanoparticles are the most utilized nanoparticles as antimicrobial operators for water treatment and in material enterprises; in gadgets, tranquilize drug transport, and agribusiness [14] Gold nanoparticles are used in the diagnosis of cancer, TiO_2 used as photocatalyst due to no toxicity (Figure 3) (Table 1).

Silver nanoparticles

Silver nanoparticles are in size from 1 to 100nm. Usually illustrated as silver, but with a high surface dimension and a modest number of molecules contain an expansive measure of oxides. Different kinds of nanoparticles can be made depending upon the application. Silver nanoparticles (AgNPs) have novel physiochemical properties which enables them to be utilized in various field including medicine, food and mechanical industries application.

Silver nanoparticles have a high surface area and part of surface molecules; subsequently, have a high antimicrobial impact when contrasted with the bulk silver [15]. Antimicrobial property of silver nanoparticles has been utilized against a wide range of human pathogens [16-18]. In many cases, the maximum capacity is still to be investigated for product assurance. In this way, there is a developing enthusiasm to use the antimicrobial property of silver nanoparticles for plant disease management [19]. Silver nanoparticles have been testing as pesticides to diminish the weight of vermin from yields. Silver nanoparticles can be combined from physical, concoction and organic strategies. Attributable to the prerequisite of outrageous conditions and dangerous synthetic substances in physical and chemical strategies,

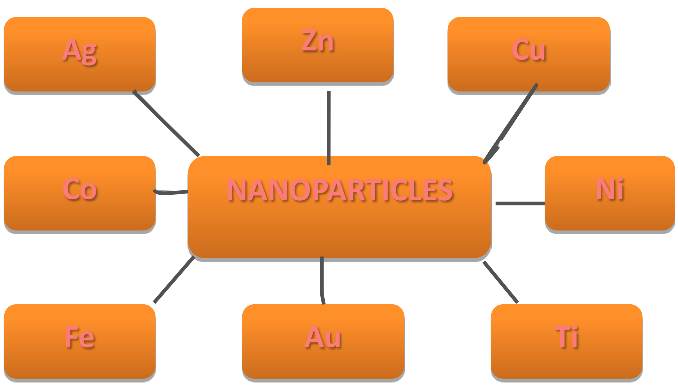

Figure 3. Different types of Nanoparticles

Table 1. Types of nanoparticles and their uses

CLASS	TYPES	USES
Metallic	Silver (Ag)	Drug delivery, Water Treatment, Electronic
	Gold (Au)	Cancer diagnosis, DNA fingerprinting, Stem cell detection
	Titanium dioxide (TiO_2)	Food additive, Water purification, medical application
	Zincoxide (ZnO)	Cosmetics, Drug delivery, biosensors.
	Copper (Cu)	Electronics, catalyst, medicine, bioanalysis
Carbon-based	Fullerene	Drug carrier, medical imaging
	Graphene	Cancer therapy, tissue engineering, bioimaging, drug delivery.
Silica-based	SiO_2	Biosensor, Drug Additives
Polymeric/ Organic	Chitosan poly (lactidoco-glycolide), polyacrylate	Drug delivery

biomaterial-based techniques are broadly utilized in these days. Being single step union and eco-friendly, extraordinary analysts have organized silver nanoparticles from different sources (plants, bacteria, fungi etc.) These silver nanoparticles have been utilized to dispose of harmful microorganisms in plants. The introduction of the snails in the soil lattice to silver nanoparticles in a research facility was observed to diminish the movement and the feasibility of the land snail and about 20% of silver nanoparticles treated snail just as the recurrence of parasitic population in the encompassing soil [20]. Spherical shaped silver nanoparticles in size range of ~10 to 20 nm using culture supernatant of Serratia sp. BHU-S4 and their effective application for the management of spot blotch disease in wheat have experimented. Silver nanoparticles exhibited strong antifungal activity against Bipolarissorokiniana, the spot blotch pathogen of wheat. Effect of silver nanoparticles with diameters of 20 nm on seeds of Fenugreek (Trigonella foenum-graecum) has been carried out [21] different concentrations of silver nanoparticles were utilized and results demonstrated that extreme seed germination. These outcomes uncovered that utilization of silver nanoparticles could be utilized to significantly upgrade seed germination potential, means germination time, seed germination record, seed power file, seedling crisp weight, and dry weight.

Zinc oxide nanoparticles

Zinc deficiency is a most basic micronutrient issue that unfavorably influences farming generation in antacid soils with calcium carbonate [22]. The soil with calcium carbonate is a noteworthy wellspring of agribusiness in bone-dry or Mediterranean conditions of the world.

Zinc oxides (ZnO) and zinc sulfates ($ZnSO_4 \bullet H_2O$) or ($ZnSO_4 \bullet 7H_2O$) are generally utilized as zinc manures to address deficiency of zinc in soils [23]. The utilization of zinc oxide nanoparticles as zinc composts may build zinc disintegration and its bioavailability in soils with calcium carbonate. Zinc oxide nanoparticles antimicrobial action over vast zinc particles since the little size under 100 nm and high surface-to-volume proportion of nanoparticles permits better connection with microscopic organisms [24].

Zinc oxide nanoparticles have the ability to induce reactive oxygen species (ROS) generation, which can lead to cell death when the antioxidative capacity of the cell is exceeded [25-28]. Zinc nanoparticles have shown to induce free radical formation in wheat, resulting in increased malondialdehyde and lower levels of reduced glutathione and reduced chlorophyll contents [29]. Zinc oxide nanoparticles utilizing leaf extract of *Moringa oleifera* in size range from 16 to 20 nm has been used as antimicrobial against bacterial strains, for example, *Staphylococcus aureus*, *Bacillus subtilis, Pseudomonas aeruginosa, Proteus mirabilis, Escherichia coli,* and other parasitic strains, for example, *Candida albicans* and *Candida tropicalis* utilizing the agar plate dissemination strategy has been tried. The most extreme zone of inhibition was seen in *Staphylococcus aureus* (23.8 ± 0.76) when contrasted with others. Circular and hexagonal zinc oxide nanoparticles from *Parthenium hysterophorus* L. have been blended by in costly, eco-friendly and basic strategy utilizing distinctive groupings of half and 25% of *Parthenium* leaf separates with size 27 ± 5 and 84 ± 2 nm, individually. These zinc oxide nanoparticles were investigated for the size-subordinate antifungal action against plant parasitic pathogens, for example, *Aspergillus flavus* and *Aspergillus niger*. A most extreme zone of inhibition was watched for 27 ± 5 nm measure zinc oxide nanoparticles against *Aspergillus flavus* and *Aspergillus niger*. *Parthenium* synthesise zinc oxide nanoparticles turned out to be great antifungal specialists and condition neighborly [30]. Round formed zinc oxide nanoparticles with a normal size of 23 to 57 nm were set up by zinc acetic acid derivation and sodium hydroxide utilizing leaves of *Catharanthus roseus* (L.) G. Wear leaf separates. The orchestrated zinc oxide nanoparticles were assessed for antibacterial action against gram-negative microscopic organisms *Escherichia coli* (ATCC 25922) *Pseudomonas aeruginosa* (ATCC 15442), gram-positive *Staphylococcus aureus* (ATCC 6538) and *Bacillus thuringiensis* (ATCC 10792). *Bacillus thuringiensis* demonstrated the protection from zinc oxide nanoparticles pursued *by Escherichia coli* though *Pseudomonas aeruginosa* was more susceptible.

Titanium dioxide (TiO_2) nanoparticles

Titanium is a hard, corrosion safe metal and its compound titanium dioxide is a mainstream photo catalyst, utilized in the production of color pigments [31]. Titanium animates generation of more starches, empowering development and photosynthesis rate in plants [32]. Titanium dioxide has appeared reactant action for the debasement of pesticides [33]. Photo catalyst property of titanium dioxide has applications in plant assurance since it doesn't frame poisonous and unsafe substances thus have strong pathogen removal efficiency. Researchers are attempting to enhance the phytopathogenic sanitization productivity of titanium dioxide thin films by dye doping and other reasonable strategies [34]. Plants are likewise the most probable selection of researchers for the synthesis of titanium dioxide nanoparticles. Circular, grouped titanium dioxide nanoparticles with a normal size of 32.58 nm from the leaf concentrate of Psidium guajava have been integrated [35]. These nanoparticles were tried against microorganisms Aeromonas hydrophila (MTCC-1739), Proteus mirabilis (MTCC-442), Escherichia coli (MTCC1677), Staphylococcus aureus (MTCC-3160) and Pseudomonas aeruginosa (MTCC-4030). The highest zone of inhibition was seen against Staphylococcus aureus (25 mm) and Escherichia coli (23 mm) when titanium dioxide nanoparticles were utilized at 20μg/mL fixation. The integrated TiO_2 nanoparticles indicated upgraded antibacterial activity than the standard anti-microbial plate, antibiotic medication which decreased the odds for the advancement of anti-infection agents obstruction of bacterial species. The concentrate from plants and titanium dioxide nanoparticles orchestrated from these had the best cancer prevention agent activity when compared with ascorbic acid. Synthesis of spherical clusters, quite polydispersed titanium dioxide nanoparticles with a size range from 36 to 68 nm by Eclipta prostrata leaf extract has been done effectively [36].

Application of nanotechnology in agriculture

Agriculture practices like farming are the foundation of a large portion of the developing nations in which a huge income originates from agribusiness and the greater part of the population relies upon it for their job. The current worldwide population is almost 6 billion with half living in Asia. A huge extent of those livings in developing or emerging nations confront everyday nourishment deficiencies because of ecological effects or political shakiness, while in the created world there is a sustenance overflow. For emerging economies, the drive is to develop dry pest resistance and drought resistance crops additionally high yield. In emerged economies, the food business is driven by buyer request which is at present for fresher and more advantageous.

In farming and other agriculture practices, nanotechnology has been utilized for the controlled arrival of agrochemicals (e.g., composts, pesticides, and herbicides) and target-specific delivery of biomolecules (e.g., nucleotides, proteins, and activators) [37]. Nanotechnology has been utilized in the development fertilizers having a potential capacity of discharge and pesticides with better wide range bother insurance productivity [38]. Nanotechnology has been utilized to transfer DNA to plant cells, improve supplement ingestion, recognize plant pathogens, control plant hormones, and in animal farming, nanocapsules have been contrived to convey antibodies. Nanotechnology has a few applications in all phases of generation, preparing, putting away, bundling and transport of rural items [39]. Be that as it may, the vast majority of the work on nanotechnology in horticulture is at the developing stage and not yet popularize.

Effect of nanoparticles on soil

Soil is the largest receptor for the nanoparticles. Behavior of nanoparticles in the soil and their risk evaluation in arable soil ecosystems or other real environmental scenarios is very topical to date40. Soil is the natural matrix and rich in natural nanoparticles both as primary particles and as agglomerates/aggregates. Artificial entry of nanoparticle into the soil may have significant effect, as they may be extremely resistant to degradation and have the potential to accumulate in the soil.

Ben-Moshe, *et al.* (2013) reported affect of nanoparticles on many microscopic properties of the soil. The protection of soil microbial biomass and diversity is one of the major issues in the field of sustainable use of soils [41]. The effect of nanoparticle on the soil depends on their concentration, soil type, and enzymatic activity of soil. At high concentrations of nanoparticles, the negative effect on dehydrogenase enzymes activity was observed [42]. Another negative effect caused by nanoparticles is the influence on the rate of soil self-cleaning as well as on the balance of nutrients, which is the basis for the regulation of the processes of plant nutrition and soil fertility improvement [43,44]. It is significant to study presence of nanoparticle in soil and their influence on soil biodiversity [45].

Soil properties, such as pH, texture, structure, and organic matter content, influence the soil microbial community and the ability of pollutants to have toxic effects on microorganism [46]. Nanoparticles could affect mobility of soil pollutants. Therefore, there is a need to compare the toxicity of the NPs in various types of soils. The soil amended with digestate and fly ash reduced the pollutant bioavailability. Another study suggests that particle size distribution and the composition of the organic matter change microbial populations in the contaminated soils [47]. Intentional influence on soil properties and composition and texture of the soil with various substances can also alter the effects of nanoparticles. Biochar is a soil minor change used for increasing soil fertility and productivity48show minimal effects of CeO_2 NPs on plants in biochar-amended soil. Interaction between NPs and biochar-amended soil is not well studied.

Effect of nanoparticles on crop growth

The rapid growth of nanoparticle production and widespread use in agriculture have increased the quick development in the production of nanoparticle its application in farming and other agriculture practices have expanded the chances of coming and blending to the nanoparticles in the field' s soil (fertile soil of forms). It is presently notable that some nanoparticles influence crop improvement, plant advancement, yield, and huge numbers of them are aggregated in various plant tissues, including the eatable piece of plant tissues. It is difficult to survey the seriousness of the nanoparticles on the eco-frameworks and human wellbeing. It is trusted that nanoparticles are most troublesome sort of poison from manages and they are undetectable in view of its very small size (Nanometer range). Different investigations of the nanoparticles impact on yields, for example, onion, spinach, coriander, wheat, rice, soybean, mung bean, radish, lettuce, grain, cucumber, and tobacco have appeared of germination, diminished shoots and root development, poisonous quality, and diminishes in photosynthetic rate and chlorophyll contents (Table 2) [49-57].

Effect of nanoparticles on plant growth

Nanoparticles related with plants causing different morphological and physiological changes, contingent upon the type and nature of the nanoparticles. The viability of nanoparticles is controlled by their substance synthesis, measure, surface covering, reactivity, and above all the portion at which they are successful [58]. Scientists from their investigations indicated both positive and negative impacts of nanoparticles on plant development and improvement, and the effect of designed nanoparticles (ENPs) on plants relies upon the structure, fixation, concentration, and biochemical and physical properties of NPs just as plant species (Table 3) [59-64].

Table 2. Effect of nanoparticles on the physiological changes in plants

Types of Nanoparticle	Concentration	Physiological changes	References
TiO_2	10-2000 mg/l	Exposure of *Lemna minor* to TiO_2 NPs increased the activities of various enzymes (POD, SOD, and CAT) below concentration of 200 mg/l because of eliminating accumulated reactive oxygen species in plant cells.	Song, *et al.* [52]
Al_2O_3	10-1000 mg/l	The activity of SOD and CAT were increased with the treatments of Al_2O_3 NPs at a concentration of 200 and 500 mg/l.	Riahi-Madvar, *et al.* [53]
ZnO	10 mg/l	Treatment of cluster bean with foliar sprays of ZnO NPs caused a significant increase in chlorophyll content (276.2 %), total soluble leaf protein (27.1%), acid phosphatase (73.5%), alkaline phosphatase (48.7%), and phytase (72.4%) over control.	Raliya and Tarafdar [54]
Fe_2O_3	20 mg/l	Increase in root activity, activity of catalase, peroxidase, superoxide dismutase, chlorophyll, malondialdehyde contents, ferric reductase activity, the root apoplastic iron content were recorded by the translocation of the significant amount of Fe_2O_3 NPs suspended in a liquid medium to various tissues of plants.	Li, *et al.* [55]
SNP ZnO	500-4,000 ppm	Application of various concentrations of both sulfur and zinc oxide nanoparticles in significantly increase the total lipids, proteins, amino acids, thiol and chlorophyll contents compared to untreated control but no significance difference has been observed among the treatments with various concentrations for both nanoparticles.	Patra, *et al.* [56]
TiO_2	200 mg/l	Application of TiO_2 NPs had a noticeable effect on chlorophyll a and b and carotenoid contents on Mentha.	Samadi, *et al.* [57]

Table 3. Effect of nanoparticles on plant species and their metabolism

Nanoparticles	Size range	Plant	Biological effects	Reference
Ag	1–10 mg L^{-1}	Triticum aestivum L.	Adversely affect seedling growth and	Vannini, *et al.* [49]
	1000–3000 mM	Pisum sativum L.	chlorophyll fluorescence	Tripathi, *et al.* [50]
		Allium cepa	Caused oxidative stress and exhibited toxicity	Cvjetko, *et al.* [51]
	5–25 nm; 0–40 mg L^{-1}	Phaseolus radiatus,	Higher accumulation in roots and shoots.	Lee, *et al.* [60]
Au	25–100 mg L^{-}	Arabidopsis thaliana,	Root length reduced by 75%. Accumulation	Taylor, *et al.* [61]
CeO_2 ZnO	0.05–0.5 g kg^{-1} soil	Glycine max	Increased ROS, lipid peroxidation, visible	Priester, *et al.* [62]
CuO	0–1000 mg L^{-1}	Conventional and	Inhibited the growth, development, nutrient	Van, *et al.* [63]
	200–500 mg L^{-1}	Ipt-cotton	Height and root length decreased, increased	Van, *et al.* [64]

Role of nanotechnology in photosynthesis

Photosynthesis is the procedure utilized by plants, green algae, and certain other microbes to prepare food. Photosynthesis is a key maker for plants on earth that changes light vitality to concoction vitality. Plants convert just 2-4 % of the accessible vitality in radiation into new plant development [65]. Lin, *et al.* 2014, grew new tobacco plants by substituting the Rubisco quality for carbon-settling in the tobacco plant, with two qualities of *cyanobacterium Synechococcus* lengthens; these newly designed plants have more photosynthetic productivity than local plants.

It was reported that SWCNTs in the detached chloroplast enlarged multiple times higher photosynthetic activity than that of controls, and improved most extreme electron transport rates, and SWCNTs empowered the plants to detect nitric oxide, a singling substance [66]. Metal nanoparticles can prompt the productivity of synthetic vitality creation in photosynthetic frameworks [67]. The chlorophyll in photosynthetic response focus binds to the AuNPs and Ag nanocrystals, in this way framing a novel half framework that may create multiple times increasingly energized electrons due to plasmon surface response and quick electron-separation. The improvement components may help in the plan of light-harvesting frameworks.

Effect of nanoparticles grain size distribution

It was found that a reasonable connection between the grain estimate distribution of the field soil (for example the sand and earth content) and the toxic effect of AgNMs towards smelling salts oxidizing microscopic organisms. Past examinations have demonstrated that the maintenance of nanomaterials for the most part increments and the bioavailability decreases in soils with a better grain estimate distribution [68]. It is discovered that the danger of AgNMs accumulation in soils with a higher sand substance or lower mud content. The connection between AgNM toxicity and sand content was not straight but there was a decent connection between the sand content and higher danger. There was a superior connection between AgNM harmfulness and mud content, with just little deviations. The maintenance of AgNMs in common soil has recently been appeared to increment in accordance with the granulometric mud content [69] which may advance the heteroaggregation of AgNM and mud standard ticles, expanding the total size and making them less accessible to microorganisms, in this way bringing about a lower lethality. The arrangement of buildings with earth particles may likewise hinder the arrival of particles. It demonstrates that the soil grain measure dissemination is by all accounts the most critical soil property affecting the lethality of AgNMs.

Effect of nanoparticles on pH of soil

Soil pH is a significant factor that directly relates to soil fertility and health. It is an indication of acidic or alkalinity of the soil. Soil pH affects the availability of the nutrients for plants. It is proved that the nature of acidity or basicity of soil depends upon the composition of the soil. In general optimum pH range for plants is 5-7. It is observed that the pH of the soil may be influenced by the accumulation of the different type of nanoparticles like Zn, Ag, Au, Cu etc. It was found that the pH of the soil also influences the toxicity of nanoparticles on the microorganisms and nematodes. The effect of organic matter and pH of the soil on the toxicity of ZnO nanoparticles on *Folsomia candida* [70]. It was found greater toxicity the effect of Zn nanoparticles then dissolved Zn on the bacterial community [71]. Very recently found that copper oxide nanoparticles may able to change the pH of paddy soil. Copper oxide nanoparticles cause an increase in the pH of soil which ultimately affects soil property. Uptake of Silver nanoparticles accumulated in soil by insects may also be influenced by the pH of the soil [72].

Soil pH seems to be the principal factor that governs concentrations of soluble metals. Zn solubility correlates negatively with pH [73]. Moreover, clay content in calcareous soil was higher than in acidic soil, which increase Zn retention in soil and hence, decreases Zn availability to microorganisms, as clays are believed to adsorb zinc ions across both ion exchange and specific adsorption. Zinc availability has also been connected to soil organic matter content. In this study, the soil organic matter content effect of content on Zn availability to microorganisms should be considered insignificant because values were very low and similar in both soils. The impacts of nanomaterials are firmly subject to the change forms they experience in nature. AgNM are oxidized in nature, and the release of silver particles might be in charge of the lethal effect [74]. Both the oxidation of AgNMs and the release of particles are reliant on the pH of the soil.

This concurs with previous findings about demonstrating that the toxicity of AgNMs towards earthworms is related with the particle content in the soil pore water [75]. The impact of ZnO nanomaterials is additionally caused for the most part by the released of particles, which proposes the outcomes ought to be similar with those watched for AgNMs. In like manner, the impact of ZnO nanomaterials on the proliferation of *Folsomia candida* demonstrated that the poisonous quality of metallic nanomaterials was reliant on soil pH, and again that the danger expanded in progressively acidic soils. The impact of Zn danger on the multiplication of *Eisenia fetida* is affected by pH for all types of Zn, reflecting the impact of pH on Zn disintegration [76].

Effect of nanoparticles on soil organic carbon

We additionally researched the effect of the natural carbon content on AgNM toxicity since this parameter may impact the impact of nanomaterials [77]. The natural carbon content differed between 0.93% and 3.85%, however there was no connection between the natural carbon substance of the five soils we tried and the lethality of either AgNM or silver nitrate.

There are signs in the writing that natural issue can change the impacts of nanomaterials, particularly those which discharge particles. For instance, the poisonous quality of AgNMs towards the freshwater zooplankton *Ceriodaphnia dubia* and *Daphnia magna* declined altogether as the broke down natural carbon content expanded [78]. AgNMs are less versatile in soils with a high substance of natural issue [79] in light of the fact that natural materials, for example, sewage slop connect with AgNMs, with sorption rates more prominent than 90% for uncoated particles [80] and lower rates for functionalized particles. Concentrates with biofilm networks and unadulterated societies have additionally appeared natural issue, for example, exopolysaccharides and humic acids can secure microorganisms and diminish the poisonous quality of AgNMs [81]. For instance, the nearness of Suwannee River humic acids made it difficult to decide an impact on the development of *Pseudomonas fluorescens*. In any case, these discoveries are for the most part from investigations in which the impact of natural carbon was tried on amphibian life forms though comparable information for soil life forms are increasingly constrained. It is already demonstrated that AgNMs and the particles discharged by them communicate with natural issue added to soil, diminishing the long haul harmful consequences for the aggregate of microbial exercises bringing about nitrate gathering [82]. The proposed mechanisms for the restraint of AgNM disintegration incorporate surface adsorption onto common natural issue (which thus forestalls AgNM oxidation and the arrival of silver particles) and the decreasing action of humic/fulvic acids which changes over oxidation items once more into silver metal [83].

Effect of nanoparticles on microbial diversity

As indicated by the examination directed by [84] TiO_2 and CuO nanoparticles diminish the microbial biomass of the form soil and action of the chemical, influenced on their structures in overflowed paddy soil. Comparable outcomes were acquired biometal who contemplated the impact of ZnO, TiO_2, CeO_2, andFe_3O_4 nanoparticles on enzymatic activities of soil (invertase, urease, catalase, and phosphatase) and bacterial networks of the saline-soluble base and black soils. The outcomes demonstrated an effect on soil chemical exercises and changes in soil bacterial network and danger on natural nitrogen obsession. Results gotten have demonstrated that a high convergence of Fe_3O_4 NPs altogether diminished the substance of microscopic organisms in the soil. Zinc oxide and CeO_2 NPs influenced the plate checks of *Azotobacter*, P-solubilizing, and-solubilizing microscopic organisms and restrain enzymatic exercises [85]. Titanium dioxide NPs diminished the plenitude of utilitarian soil microscopic organisms and enzymatic activities and hindering impact on microbial action, occurrence, and diversity [86,87]. The information provided by [88] Maliszewska (2016) reported that the biogenic Au NPs up to the grouping of 33 mg kg^{-1} don't influence the soil properties and their processes and can be delegated not destructive. Be that as it may, antibacterial exercises (development of a zone of inhibition) were seen on clinical disconnects (*Bacillus subtilis*, *Escherichia coli*, *Klebsiellapneumonia, Pseudomonas aeruginosa, Salmonella typhi, and Staphylococcus aureus*) treated with ZnO NPs incorporated by organic and concoction techniques [89].

Copper ions, released from the Cu NPs, were considered as a major cause of lethality to both the pathogenic and the beneficial bacteria [90]. It was investigated the effect of CuO and AgNPs on leaf microbial decomposition showing that exposure to these NPs led to a decrease in leaf decomposition rate (Table 4) [91-95].

The researchers observed that TiO_2, at high concentrations, can disturb the symbiosis relationship between plant and bacteria and have a negative effect on the growth of clover. In natural soil, the mobility of the nanoparticles was weak and no increase in the uptake of titanium dioxide by the plants was found.

The mobility of MWCNT in soils was also weak; the experiments showed a concentration-independent uptake of MWCNT by the plants and a reduction in the number of red clover blossoms in the case of high concentrations. Both TiO_2 and MWCNT in very high concentrations resulted in a change in the composition of the microbial communities that interact with the plants (Table 5) [96-99].

Conclusion

Nanobiotechnology accelerated almost every sector of agriculture sciences and crop research. It is well understood that the use of nanomaterial for the scientific and agriculture field enables a lot of advantages over conventional methods. Biofertilizers based on nanotechnology is quite useful for plant growth and developments.

Table 4. Effect of nanoparticles on soil microbial community and enzymes

Nanomaterials	Major effect	References
Au	Hinderance in enzymatic activities of soil	Asadishad, *et al*.
TiO_2	The loss in diversity of the bacterial community	Ge, *et al*. [92]
Cu	Decreases C, N Biomass	Kumar, *et al*. [93]
Ag	Loss of microbial community, hindrance in enzymatic activities	Peyrote, *et al*. [73] Colman, *et al*. [74]
Mixture of Cu and Fe	Loss of microbial community	Ben-Mosey, *et al.* [41]
Mixture of Co, Fe, Ni and Ag	Not much effect on the soil community	Shah, *et al*. [10]
Ag	β-Glucosidase, acid phosphatase, dehydrogenase, Urease	Hnsch and Emmerling [94]
C_{60}	eucine-aminopeptidase, β-cellobiohydrolase, acid phosphatase, β-Glucosidase, chitinase, xylosidase	Tong, *et al*. [95]

Table 5. Effect of nanoparticles on soil nematodes community

Test Nanoparticles	Test species	Author/Year
MWNT, SWNT	*Eisenia foetida*	Petersen, *et al.* [96]
Tio_2, ZnO	*Eisenia foetida*	Hu, *et al*. [97]
Al_2O_3	*Eisenia foetida*	Coleman, *et al*. [98]
Pt	*Caenorhabditis elegans*	Kim, *et al*. [99]
Ag	*Caenorhabditis elegans*	Roh, *et al.* [81]
ZnO	*Caenorhabditis elegans*	Ma, *et al.*
CeO_2, TiO_2	*Caenorhabditis elegans*	Roh, *et al*. [81]

Biopesticides and no fungicides are more effective against disease and harmful insects. DNA delivery in crop research has become very easy with the help of nanobiotechnology. Uncontrolled and unregulated accumulation of nanomaterials in soil is a matter of concern. Since toxicity of nanomaterial is not unknown from late last decades. Investigations indication toxicity of nanomaterials is the emerging serious issue. Microbial community and soil health which directly or indirectly related to human health and wellbeing must be protected from the unnecessary deposition of nanomaterials.

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