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An overview on toxic effect of nanoparticles in plants and future perspective

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ABSTRACT
The current situation demands an urgency to satisfy nutritional demand of the growing world population. In this regard, nanotechnology has widely contributed to the agrotechnological revolution. Since then, nanotechnology has become a new-age material to transform modern agricultural practices. The variety of material-based nanoformulations such as nanopesticides, nanoherbicides, nanofungicides, nanofertilizers, and nanosensors has widely been developed for plant health management and soil improvement. The plant and nanomaterial interaction has opened a new debate towards health safety. Therefore, it is important to address the health issues and environmental hazards of nanoparticles application in plant science. This review has focused on phytotoxicity of nanoparticles on plants and also collected data on various routes, behavior and capability of the plant. Therefore, this paper has comprehensively tried determining interactions of plant species with nanomaterials.
Keywords: *Toxicology, bioaccumulation, nanoparticles, pigment*

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INTRODUCTION

Nanomaterials with unique physico-chemical properties provide resourceful materials for functionalization with biomolecules. Nanoparticles (NPs) existences in the environment were long before the nanotechnology era started. The reports on involvement of nanoparticles have been from ancient history for example application of nanofibers in ceramic and the most ancient pigment "Egyptian blue" was also noticed when mixture of quartz and nanoparticulate glass were mixed [1].Since there was not much evidence and terminology related to nanotechnology till 1958, thenRichard Feynman delivered a talk "Plenty of room at bottom" at American Physical Society in 1959 thus he brought the concept of nanotechnology [2]. Nanomaterials since then have found lots of applications in different sectors such as nanomedecine and pharmacokinetics, especially in diagnosis and therapeutics, and at the same time, they promise opportunities in energy storage, medicine and environmental technology [3-4]. According to different surveys, there are more than 1814 consumer products available on the market from 622 companies. Due to the continuous demand of nanoparticles, its production is undoubtedly expanding and their use leading to their release into the environment. There are various reports available which indicate negative effect of nanoparticles on plants. Surplus reports have already been published confirming the harmful effects of nanoparticles on *Sorghum bicolor* [5], *Lolium multiform* [6], *Triticum aestivum* [7], *Vigna radiate*[8].Although diverse reports on nanotoxicity of nanomaterials are available, still there are very few reports available to reveal its actual fate in the environment. As this study of nanoparticle toxicity is an emerging discipline, the gaps in the knowledge on nanoparticles ecotoxicity could be filled up by carrying out research in this area [9].
According to the Department of Economic and Social Affairs/Population Division of United Nations a survey report, on "World Population to 2300" showed that the current population of the world is more than 7.4 billions, however, in future 2050 it is estimated to be more than 10.6 billion. This large population requires food to survive. There are two major sources of food viz., meat based products and agriculture based products. Meat based products requires lots of care and measure to get the yield. Plants are the main source of dietary for human beings and animals hence, knowledge of the nanoparticle on plants, soil and environment is crucial. However, the agriculture based products are easy to produce compared to meat based products. In agriculture, different fertilizers and pesticides are applied to

enhance the product quality and quantity. However, use of chemicals leads to adverse effects as well as pollute the ecosystem and environment. Thus, an alternative and efficient, less toxic material development is required to replace these harmful fertilizers and pesticides. Thus, this review briefly outlines nanomaterial and plant interactions.

NANOMATERIAL IMPACT ON PLANTS

The comprehensive report of nanoparticle phytotoxicity is very limited, but at the same time it becomes very important for implementing nanotechnology as an innovative approach in agriculture tools and products [10]. Current studies of nanoparticles on plants which are available have also shown unrealistic reports only based on high dose concentration and exposure [11]. The reports have revealed that excess of metal and metal-oxide based nanoparticles trigger an oxidative stress around the cell by interfering with the electron transport chain as well as by rupturing the reactive oxygen species (ROS) detoxifying machinery [12-15]. The stress has resulted plants to lose their secondary metabolites, hormonal misbalance and growth is negatively retarded. Further studies have reported that on exposure of various types of nanoparticles (e.g., zinc oxide, fullerenes, or titanium dioxide), significant number of genes involved in phosphate-starvation, pathogen and stress responses have been repressed. This has lead plants to achieve poor root development and defense mechanism in *A. thaliana* [16]. A recent systems biology approach on various plants such as tobacco, rice, rocket salad, wheat, and kidney beans reported on exposure of various metal nanoparticles, provoked a generalized stress response, with the prevalence of oxidative stress components [17].

There are many examples for toxic action of differently produced and sized nanoparticles of various compositions. Impacts of silver nanoparticles on plants: a focus on the phytotoxicity and underlying mechanism has been studied [18]. It has been found that colloidal silver exert phytotoxicity effects on crops which showed enhanced growth on treatment with nanoparticles with respect to their dose and size [19]. In some reports, it has been found that AgNPs phytotoxicity is much higher compared to Ag ionic solutions on seed germination of *Brassica nigra*[20]. Phytotoxicity evaluation for silica nanoparticles against *Arabidopsis thaliana* has been studied [21]. It was noticed that, it has toxic effects for the negatively charged 50 and 200 nm silica nanoparticles. In addition, size dependent uptake of nanoparticles was also observed. In addition, it was found that silica scaffolds showed significant uptake in root system for silica nanoparticles [22].The influence of ZnO nanoparticles was evaluated using garden pea based rhizobium legume symbiosis system and the observation at the beginning did not show much influence on seed germination but changed drastically with change in the root length. However, the results of the study revealed the negative effects of ZnO nanoparticles on plant, as it decreased the leaf surface area, transpiration, lateral root and stem lengths. In addition, it influenced the root nodule formation leading to delayed nitrogen fixation and caused senescence. Moreover, nano ZnO nanoparticles found to get attached onto the leaf surface which is hazardous for the symbiotic rhizobium legume system [23].

Toxicity evaluation have been conducted many times using bulk and hybrid nanoparticles of the metal in Green Pea (*Pisum sativum* L.) [24]. The studies have revealed that exposure of Zn metal, regardless of type or its concentration, had very little and slow impact on the biochemical profile (protein or carbohydrate) of the green pea. The amount of **acid**-soluble (glutelin),) water-soluble (albumin), salt-soluble (globulin) and alcohol-soluble (prolamin) protein fractions remained unaltered in all treatments with salt and metal nanoparticles. There was a decrease in glutelin amount (50%) at 1000 mg/kg doped treatment, compared to control, but due to large variability and modest replicate numbers, the decrease was statistically insignificant. The seed quality was affected most by the doped NPs at 1000 mg/kg where nutrient content and carbohydrate profile (sucrose) changed. Although, the study didn't conclude the mechanism, but it summarized that ion release and coating was assisted by uptake of nanoparticles, which might be the possible pathways of concern in future. Additional study is immediately required that deals with broader implications of nanoparticle doping and coating for safe use in food industry. The fate of engineered nanoparticle and its disposition in the environment is warranted. Phytotoxicity of water-soluble fullerene has also been analyzed on transgenic seeds using fluorescent markers. There has been sharp reduction in the root length. Fluorescent images demonstrated the abnormalities in root tip like hormones circulation, microtubule organization, mitochondrial activity and cell division. This study opened a new area for using fluorescent imaging for phytotoxicity analysis in plants [25].Wheat (*Triticum aestivum* L.) is one of the most important crop which is continuously been cultivated worldwide. The research findings on wheat have been studied using silver nanoparticles (AgNPs). Wheat root exposed under different concentrations of AgNPs (10, 20, 40 and 50 ppm) for three different time durations (8, 16 and 24 h) exhibited various chromosomal aberrations, such as incorrect orientation at metaphase, chromosome, metaphasic plate distortion, spindle dysfunction, stickiness, aberrant movement at metaphase, fragmentation, scattering, unequal separation, scattering, chromosomal gaps, multipolar anaphase, erosion, and distributed and lagging chromosomes. These results have demonstrated that the root tip of wheat can readily interact with the AgNPs and its internalization can affect the cell normal functions [26]. In another study, silver nanoparticles inhibited seed germination of the common grass (*Lolium multiflorum*). When 40 mg·L^{-1} of GA-coated Ag nanoparticles was exposed to the seedling, it failed to develop the root, fuzzes became vacuolated, collapsed and broken its epidermis. Cysteine was found to mediate the toxicity in plant. It was also observed that, silver was oxidized inside the plant tissues. This study clearly showed that, certain bio based receptors led to the delivery of silver nanoparticles [27].

The phytotoxicity of ZnO nanoparticles and bulk salt was analyzed following hydroponic conditions on alfalfa (*Medicago sativa* L.) for 30 days. The level of toxicity was analyzed based on the total protein content, dry biomass, catalase activity and bioaccumulation. The research revealed about 80 and 25 % reduction in root and shoot biomass. It was also concluded that ZnO nanoparticles exhibited less toxicity compared to bulk ZnO and $ZnCl_2$[28].It should be noted that a significant studies on nanoparticles phytotoxicity were conducted at laboratory level. These results do not always correlate with the results of field studies. All these points make it difficult to extrapolate the available data on the phytotoxicity of nanoparticles in terms of natural and anthropogenic ecosystems.

INTERACTION MECHANISM OF NANOPARTICLES WITH PLANT

Understanding the interaction of nanoparticles on plants is very crucial in categorizing its mechanism through various processes such as phytotoxicity, nanoparticle uptake and through translocation. Available reports have revealed that all the above mentioned mechanistic interactions often depend on type of plant, species, size, chemical nature, chemical stability, and its hybrid behavior.

Phytotoxicity mechanism

Phytotoxicity studies involving higher plants are important criteria for understanding the toxicity of nanoparticles. Most of the studies have been on both negative and positive or inconsequential effects of nanoparticles on plant [29]. From a toxicological perception, surface area of the materials and its particle size are important characteristics of a nanoparticle. The relationship between size and surface area is inversely proportional to each other. As the size of the particles decreases, its surface area increases sharply, and allows a greater percentage of atoms or molecules to be displayed on the surface rather than the interior of the nanoparticles [30]. The potential of reactive group bound with nanoparticles increase with increase in surface area [31]. The change in the topography and physico-chemical properties of nanoparticles could be responsible for a number of material interactions that result in toxicological effects [32]. The percentage increase in inflammation is mainly because of much greater surface area of the nanoparticles for similar masses of material [33]. Therefore, in conclusion, we demonstrated direct exposure of nanoparticles causing significant phytotoxicity and it emphasizes the need for developing disposal techniques for wastes containing nanoparticles.

Nanoparticle uptake mechanism

The major gap on uptake mechanism of nanoparticle towards plant is due to inconsistent research publications and incomplete information [34]. Hartley & Lepp (2008)reported that uptake and adherence of nanoparticles on plant roots take place via chemical or physical process [35]. The accumulation and uptake of nanoparticles has largely been due to various factors such as type, size, and the composition of the plant. Without a doubt, the verification on the uptake mechanism of nanoparticle is limited and is focused on stock solutions rather than the actual concentration [36]. Various mechanisms on uptake have been proposed but many have suggested that the entry of nanomaterials could be due to its binding with carrier protein, through aquaporin, by ion channels, or through endocytosis [37]. This uptake would have been due to the greater surface area-to-mass ratio of the nanoparticle compared to the bulk metals [38]. It has also been noticed that nanomaterials do form complexes with membrane transporters or root exudates before being transported into the plants. Metal or metal oxide nanoparticles uptake by plant has been due to ion transport channel. However, the relation between nanomaterial uptake and the type of plant remain unknown and are open to exploration.

Nanoparticle translocation mechanism

The nanomaterials are intermediate in nature towards its mobility and export prior to its translocation. Yang and Ma (2010) have suggested that the translocation of nanoparticles is highly dependent on its volume being exported in nature and type of plant species [39]. The nanomaterials generally move from leaves to roots, stem, and developing grain, and further from one root to another. The translocation mechanism of nanoparticle gets initiated with its penetration across cell walls and plasma membrane of root cells. One of the main passages for uptake and transportations of nanoparticles to the shoot and leave(s) of plant is the Xylem [40].The penetration rate of engineered nanoparticles was studied with leek (*Allium porrum*), and found that its pathway in the leaf was followed with the stomatal pathway [41].

FUTURE PERCEPTION

Phytotoxic studies of nanomaterials are of great concern in terms of their application in agricultural fields. This review addressed few major aspects such as the toxicity, and its basic mechanism in plants. But still there are many faces of nanoparticle transport which needs to be uncovered. There have been many research findings dealing with nanoparticles phytotoxicity but there is still a strong need to fill the knowledge gap on the following aspects a) production of nontoxic nanomaterials with positive interaction on plants, b) improvement in translocation of nanomaterials, c) Improvement in defense mechanisms in plants through functionalized nanomaterials, d) high yield production and growth of plant through nano-suspension and nanoemulsion. Thus, by understanding the above gaps points we can make use of many parts of the plants in edible form with safer limits for human consumption and can see tremendous use of nanoparticles in agricultural applications.

CONCLUSION

This purpose for collecting data for review was to develop understanding and bring awareness on toxicity of synthesized nanoparticles on plants and its impact on health and environment. Toxicity studies concluded that nanoparticles interaction with plants is mainly dependent on surface energy, chemical composition, particle size, species and different techniques applied to evaluate it. The uptake and translocation of nanoparticle helped us to understand the kinetics of nanoparticle in plants. The increasing applications of nanoparticles in soil are a matter of great importance to elucidate the toxicity of nanoparticles. Additional studies are very much required to understand the immobilization of nanoparticle in soil and its uptake by plant and the mentioned knowledge gap has to be filled.

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CONFLICTS OF INTEREST

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REFERENCES

1. Accorsi G, Verri G, Bolognesi M, Armaroli N, Clementi C, Miliani C, Romani A. (2009).The exceptional near-infrared luminescence properties of cuprorivaite (Egyptian blue). *Chem Commun*.;3392–3394.
2. Hulla JE, Sahu SC, Hayes AW. (2015). Nanotechnology: History and future. *Hum Exp Toxicol*.; 34:1318–1321.
3. Zhu X, Zhu L, Chen Y, Tian S. (2009). Acute toxicities of six manufactured nanomaterial suspensions to *Daphnia magna*. *J Nano Res*.; 11:67-75.
4. Khan MN, Mobin M, Abbas ZK, AlMutairi KA, and Siddiqui ZH. (2017). Role of nanomaterials in plants under challenging environments. *Plant Physiol Biochem*.; 110:194–209.
5. Krishnaraj C, Ramachandran R, Mohan K, Kalaichelvan PT. (2012). Optimization for rapid synthesis of silver nanoparticles and its effect on phytopathogenic fungi. *Spectrochim ActaA Mol Biomol Spectrosc*.; 93:95–99.
6. Vannini C, Domingo G, Onelli E, Prinsi B,Marsoni M,Espen L, Bracale M. (2013). Morphological and proteomic responses of *Eruca sativa* exposed to silver nanoparticles or silver nitrate. *PLoSONE*.;8(7):68752.
7. Jasim B, Thomas R, Mathew J, Radhakrishnan EK. (2017). Plant growth and diosgenin enhancement effect of silver nanoparticles in Fenugreek (*Trigonella foenum-graecum* L.). *Saudi Pharm J*.;25(3):443–7.
8. Zafar H, Ali A, Ali JS, Haq IU, Zia M. (2016). Effect of ZnO nanoparticles on *Brassica nigra* seedlings and stem explants growth dynamics and antioxidative response. *Front PlantSci*.;7:535.
9. Modlitbová P, Porízka P, Novotný K, Drbohlavová J, Chamradová I, Farka Z, *et al*. (2018). Short-term assessment of cadmium toxicity and uptake from different types of Cd-based quantum dots in the model plant *Allium cepa* L. *Ecotoxicol Environ Saf*.;153:23-31.
10. Servin AD and White JC. (2016). Nanotechnology in agriculture: next steps for understanding engineered nanoparticle exposure and risk. *Nano Imp*.;1:9–12.
11. Miralles P, Church T and Harris AT. (2012). Toxicity, uptake, and translocation of engineered nanomaterials in vascular plants. *Environ Sci Technol*.;46:9224–9239.
12. Dimkpa CO, McLean JE, Martineau N, Britt DW, Haverkamp R and Anderson AJ. (2013). Silver nanoparticles disrupt wheat (*Triticum aestivum* L.) growth in a sand matrix. *Environ Sci Technol*.;47:1082–1090.
13. Faisal M, Saquib Q, Alatar AA, Al-Khedhairy AA, Hegazy AK and Musarrat J. (2013). Phytotoxic hazards of NiO-nanoparticles in tomato: a study on mechanism of cell death. *J Hazard Mater*.; 250(251):318–332.
14. Pakrashi S, Jain N, Dalai S, Jayakumar, J, Chandrasekaran PT, Raichur AM, *et al.* (2014).*In vivo* genotoxicity assessment of titanium dioxide nanoparticles by *Allium cepa* root tip assay at high exposure concentrations. *PLoSONE*. 9(2);e98828.

15. Pagano L, Servin AD, De La Torre-Roche R, Mukherjee A, Majumdar S, Hawthorne J, *et al*. (2016). Molecular response of crop plants to engineered nanomaterials. *Environ Sci Technol*.; 50:7198–7207.
16. Sanzari I, Leone A and Ambrosone A. (2019). Nanotechnology in Plant Science: To Make a Long Story Short. Front *Bioeng Biotechnol*.; 7:120.
17. Ruotolo R, Maestri E, Pagano L, Marmiroli M, White JC and Marmiroli N. (2018). Plant response to metal-containing engineered nanomaterials: an omics-based perspective. *Environ Sci Technol*.; 52: 2451-2467.
18. Yan A & Chen Z. (2019). Impacts of Silver Nanoparticles on Plants: A Focus on the Phytotoxicity and Underlying Mechanism. *Int J Mol Sci*.;20(5):1003.
19. Thuesombat P, Hannongbua S, Akasit S, Chadchawan S. (2014). Effect of silver nanoparticles on rice (*Oryza sativa L*. cv. KDML 105) seed germination and seedling growth. *Ecotoxicol Environ Saf*.;104:302-309.
20. Amooaghaie R, Tabatabaei F, Ahadi AM. (2015). Role of hematin and sodium nitroprusside in regulating Brassica nigra seed germination under nanosilver and silver nitrate stresses. *Ecotoxicol Environ Saf*.;113: 259-270.
21. Milewska-Hendel A, Zubko M, Stróż D, Kurczyńska EU. (2019). Effect of Nanoparticles Surface Charge on the *Arabidopsis thaliana* (L.) Roots Development and Their Movement into the Root Cells and Protoplasts. *Int J Mol Sci*.;20(7):1650.
22. Slomberg DL, Schoenfisch MH. (2012). Silica Nanoparticle Phytotoxicity to *Arabidopsis thaliana*. *Environ Sci Technol*.;46(18):10247–10254.
23. Huang YC, Fan R, Grusak MA, Sherrier JD, Huang CP. (2014). Effects of nano-ZnO on the agronomically relevant Rhizobium–legume symbiosis. *Sci Total Env*.;497–498(1): 78-90.
24. Mukherjee A, Sun Y, Morelius E, Tamez C, Bandyopadhyay S, Niu G, White JC, Peralta-Videa JR and Gardea-Torresdey JL. (2016). Differential Toxicity of Bare and Hybrid ZnO Nanoparticles in Green Pea (*Pisum sativum* L.): A Life Cycle Study. *Front Plant Sci*.; 6:1242.
25. Liu Q, Zhao Y, Wan Y, Zheng J, Zhang X, Wang C, Fang X, Lin J. (2010). Study of the Inhibitory Effect of Water-Soluble Fullerenes on Plant Growth at the Cellular Level. *ACS Nano*.; 4(10):5743–5748.
26. Abdelsalam NR, Abdel-Megeed A, Ali HM, Salem MZM, Al-Hayali MFA, Elshikh MS. (2018). Genotoxicity effects of silver nanoparticles on wheat (*Triticum aestivum* L.) root tip cells. *Ecotoxicol Environ Saf*.;155:76-85.
27. Yin L, Cheng Y, Espinasse B, Colman BP, Auffan M, Wiesner M, Rose J, Liu J, Bernhardt ES. (2011). More than the Ions: The Effects of Silver Nanoparticles on *Lolium multiflorum*. *Environ Sci Technol*.;45(6):2360–2367.
28. Bandyopadhyay S, Plascencia-Villa G, Mukherjee A, Rico CM, José-Yacaman M, Peralta-Videa JR, Gardea-Torresdey JL. (2015). Comparative phytotoxicity of ZnO NPs, bulk ZnO, and ionic zinc onto the alfalfa plants symbiotically associated with Sinorhizobium meliloti in soil. *Sci Total Env*.;515–516:60-69.
29. Singh M, Renu, Kumar V, Upadhyay SK, Singh R, Yadav M, Seema, Kumari S, Sharma AK, Manikanadan S. (2021). Biomimetic synthesis of silver nanoparticles from aqueous extract of *Saraca indica* and its profound antibacterial activity. *Bioint Res Appl Chem*.;11(1):8110-8120.
30. Singh M, Manikanadan S, Yadav M, Kumar S, Sehrawat N, Meashi V *et al*. (2020). Biofunctionalized Gold Nanoparticles: A Potent Probe for Profound Antibacterial Efficiency through Drug Delivery System. *Asia J Biolog Life Scie*.;9(2):139-44.
31. Singh M, Saurav K, Majouga A, Kumari M, Kumar M, Manikandan S, Kumaraguru AK. (2015). The cytotoxicity and cellular stress by temperature fabricated polyshaped gold nanoparticles using marine macroalgae, *Padina gymnospora*. *Biotech App Biochem*.; 62(3): 424-432.
32. Singh M, Kalaivani R, Manikandan S, Sangeetha N, Kumaraguru AK. (2012). Facile green synthesis of variable metallic gold nanoparticle using *Padina gymnospora*, a brown marine macroalga. *Appl Nanos*.;2 (8): 1-7.
33. Singh M, Kumar M, Kalaivani R, Manikandan S, Kumaraguru AK. (2012). Metallic silver nanoparticle: a therapeutic agent in combination with antifungal drug against human fungal pathogen. *Biopro Biosys Engin*.; 36(4):407-415.
34. Nevius BA, Chen YP, Ferry JL and Decho AW. (2012). Surface-functionalization effects on uptake of fluorescent polystyrene nanoparticles by model biofilms. *Ecotoxic*.;21(8):2205–2213.
35. Hartley W and Lepp NW. (2008). Remediation of arsenic contaminated soils by iron-oxide application, evaluated in terms of plant productivity, arsenic and phytotoxic metal uptake. *Sci Total Environ*.;390(1):35–44.
36. Smirnova E, Gusev A, Zaytseva O *et al*. (2012). Uptake and accumulation of multiwalled carbon nanotubes change the morphometric and biochemical characteristics of Onobrychis arenaria seedlings. *Front Chem Sci Engin*.;6(2):132–138.
37. Kurepa J, Paunesku T, Vogt S *et al*. (2010). Uptake and distribution of ultrasmall anatase TiO_2 alizarin red S nanoconjugates in *Arabidopsis thaliana*. *Nano Let*.;10(7) 2296-2302.
38. Larue C, Veronesi G, Flank A, Surble S, Herlin-Boime N and Carrière M. (2012). Comparative uptake and impact of TiO_2 nanoparticles in wheat and rapeseed. *J Toxico and Environ Health*.;75(13–15):722-734.
39. Yang K and Ma Y. (2010). Computer simulation of the translocation of nanoparticles with different shapes across a lipid bilayer. *Nat Nanotech*.;5(8):579-583.
40. Pola M, Tamara LC and Andrew TH. (2012). Toxicity, uptake, and translocation of engineered nanomaterials in vascular plants. *Environ Sci and Technol*.; 46(17):9224–9239.
41. Mittal D, Kaur G, Singh P, Yadav K and Ali SA. (2020). Nanoparticle-based sustainable agriculture and food science: recent advances and future outlook. *Front Nanotechno*.; 2:579954.

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