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A review on applications of metal oxide Nanopaticles in agriculture

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Abstract
In this review, we emphasize that the advantages associated with application of metal oxide nano particles to enhance agricultural productivity. The appropriate use of micronutrients in form of nanoparticles is a key factor for a sustainable land management system (Gransee 2004). Metal oxide nano paricles acting as the essential micronutrient elements include zinc, copper, iron, manganese, boron and molybdenum. These are essential mineral element for plants and is nontoxic to organisms. Micronutrients are essential for crop production in the present scenario of soil fertility and their deficiency drastically affects the growth, metabolism and reproductive phase of crop plants. Micronutrients are essential elements that are used by plants in small quantities. Yield and quality of agricultural products increased with micronutrients application, therefore human and animal health is protected with feed of enrichment plant materials. Each essential element only when can perform its role in plant nutrition properly that other necessary elements are available in balanced ratios for plant. In this study, we took advantage of nanotechnologies to systematically investigate the antibacterial mechanisms of metal oxide nanoparticles (MONPs).

Keywords: Metal oxide nanoparticles, micronutrients, soil fertility and agriculture

Introduction
Agriculture is the backbone of the economy of many countries and in developing countries it is considered the main livelihood of the rural population (Mishra *et al*., 2014) [25]. Agriculture is the main source of food and is expected to feed ever increasing population worldwide (FAO, 2014) [6]. The importance of agriculture to all human society characterized more than ever with increasing populations. The most important need of human is access to food and food supply is associated with agriculture. Nanotechnology deals with the production and usage of materials with nanoscale dimensions for better yield of agriculture. Nanoparticles (NPs) is an emerging research trend in green nanotechnology as this method is nontoxic or less toxic, eco-friendly, efficient, and cost-effective as compared to other conventional physical and chemical methods. Nanomaterials can have different biological impacts on various plant species. To enhance defense systems, growth, and yield in plants. Notably, this enhanced defense system may not only be directly linked to the reduced toxicity, but also to the potential nutritional value of the NPs themselves, especially for the essential micronutrients necessary for host defense. We also posit that these positive effects are likely a result of the greater availability of the nutrients in the “Nano” form. The use of nanoparticles in form of metal oxide nanoparticles for the prevention and control of plant diseases is a promising and valuable topic because of their increased effectiveness, durability and, particularly, their high specific surface area, which can stimulate interactions with living cells (Kang *et al*., 2008) [10].

ZnO nano particles
Zinc oxide NPs have potential to boost the yield and growth of food crops. Peanut seeds were treated with different concentrations of zinc oxide nanoparticles. Zinc oxide nanoscale treatment (25 nm mean particle size) at 1000 ppm concentration was used which promoted seed germination, seedling vigor, and plant growth and these zinc oxide nanoparticles also proved to be effective in increasing stem and root growth in peanuts [Prasad *et al*. 2012] [21].
The colloidal solution of zinc oxide nanoparticles is used as fertilizer. This type of nanofertilizer plays an important role in agriculture. Nanofertilizer is a plant nutrient which is more than a fertilizer because it not only supplies nutrients for the plant but also revives the soil to an organic state without the harmful factors of chemical fertilizer. One of the

advantages of nanofertilizers is that they can be used in very small amounts. An adult tree requires only 40–50 kg of fertilizer while an amount of 150 kg would be required for ordinary fertilizers. Nanopowders can be successfully used as fertilizers and pesticides as well [Zorin *et al*. 2001, Raikoa *et al*. 2006] [24, 13]. The yield of wheat plants grown from seeds which were treated with metal nanoparticles on average increased by 20–25% [Batsmanova *et al* 2013] [11].

ZnO NPs were synthesized using plant leaf extract (*Aloe barbadensis Mill*). Their formation was validated using a number of optical spectroscopic and electron microscopic techniques. The particle size of green ZnO NPs averaged as 35nm which was far smaller than that prepared by conventional chemical methods for comparison purpose (e.g., 48nm). Although both types of ZnO NPs were spherical with high crystallinity, the former is likely to better reflect the strong reducing and capping capability of the leaf extract. The suitable concentrations of ZnO NPs for seedling emergence and germination of wheat (*Triticum aestivum* L.) were then explored at varying NP levels (0, 15, 62, 125, 250, and 500mg/L). Accordingly, the ones treated with green ZnO NPs grew better than the control seeds. Moreover, the wheat seed samples treated with a moderate amount (e.g., 62mg/L) of green ZnO NPs showed most significant enhancement ($P<0.005$) in their root and shoot length relative to other concentration levels or to the chemically synthesized ones (e.g., by 50% and 105%, respectively). As such, the potential of green synthesized ZnO NPs has been recognized as a nano-based nutrient source for agricultural applications.

CuO NPs

Copper is an essential micronutrient incorporated into many proteins and metalloenzymes, and plays a significant role in the health and nutrition of plants. Copper nanoparticles due to unique properties are more efficient than bulk copper particles in activity and functioning. Due to antimicrobial activity copper nanoparticles are finding new applications in agriculture, healthcare and industry. We review here the biological synthesis of copper nanoparticle using plant extracts and microorganisms; antibacterial and antifungal activity of copper nanoparticles and the impact of copper nanoparticles on crops and pathogenic microorganisms Crop plants treated with nanoparticles (NPs) show enhanced growth and crop yield without causing any toxic effects at lower doses. Recent studies suggest that copper (Cu) oxide metallic nanoparticles are found to be essential micronutrients and act as a plant growth promoting complex. Nanoparticle exposure could alter the cell signaling of molecular level, which leads to promotion of cell growth, and development of crop plants. NPs at lower dose could significantly increase the vegetative growth and crop yields. The effects of NPs on plant growth and yield may vary from species to species. The NPs could regulate different morphological, physiochemical, molecular and metabolic processes in crop plants. The impact of copper oxide nanoparticles on signaling, gene expression, seed germination, seedling growth, and crop yield in plants. The interactions between nanoparticles exposure and plant responses, including their uptake, transport, internalization, and antioxidant activity could revolutionize crop productivity through increased plant growth, antioxidative enzyme level, nutrient uptake and yield potential significantly in different crop plants.

FeO NPs

The effectiveness of iron oxide nanoparticles (Fe_2O_3 NPs) as a fertilizer to replace traditional Fe fertilizers, which have various shortcomings. The effects of the Fe_2O_3 NPs and a chelated-Fe fertilizer (ethylenediaminetetraacetic acid-Fe; EDTA-Fe) fertilizer on the growth and development of peanut (*Arachis hypogaea*), a crop that is very sensitive to Fe deficiency, were studied in a pot experiment. The results showed that Fe_2O_3 NPs increased root length, plant height, biomass, and SPAD values of peanut plants. The Fe_2O_3 NPs promoted the growth of peanut by regulating phytohormone contents and antioxidant enzyme activity. The Fe contents in peanut plants with Fe_2O_3 NPs and EDTA-Fe treatments were higher than the control group. However, the Fe_2O_3 NPs adsorbed onto sandy soil and improved the availability of Fe to the plants. Together, these results show that Fe_2O_3 NPs can replace traditional Fe fertilizers in the cultivation of peanut plants.

In order to assess the effects of green synthesized nanoparticles (GNPs) of Fe oxides on plant growth traits, photosynthetic capacity and nutritional quality of red radish (cv. Champion). This study revealed that growth and yield of radish plants significantly increased by FeO nanoparticles application. The maximum vegetative growth, leaf pigments and root quality (diameter and weight) were recorded in plants treated with FeO (GNPs). Furthermore, the application of FeO significantly improved the concentration of anthocyanins, phenols, tannins, flavonoids, crude protein and carbohydrates contents in radish root. Similar trends were noted in photosynthesis rate, water use efficiency and values of Fe contents. In addition, health risk index for Fe was less than 1, which indicated to red radish plants supplied with FeO GNPs were free of risks on human health. It was concluded that application of FeO GNPs can be considered as appropriate strategy for improving yield and nutritional status of red radish. The application of Fe NPs increased the Fe concentrations in roots, shoots, and grains. Overall, the NPs play a major role in the increase in biomass and nutrients in wheat.

AgO NPs

Silver nanoparticles have strong antifungal, antibacterial, antiviral and antiinflammatory potential. Silver ions inactivate thiol groups in the fungal cell wall, resulting in cell lysis and DNA mutation, thereby disrupting membrane processes (such as the membrane electron transport chain and transmembrane energy metabolism) and dissociating enzyme complexes, and ultimately blocking the respiratory chain in the fungus. The relationship between the size of nanoparticles and their efficiency and antimicrobial potential is an inverse one. Silver nanoparticles have great roles in disease management in plants.

Si-NPs

Si-NPs may directly interact with plants and impact their morphology and physiology in various ways, including the addition of structural color to the plants, and help in improving plant growth and yield (Bao-shan *et al*. 2004; Strout *et al*. 2013; Suriyaprabha 2014; Siddiqui and Al-Whaibi 2014) [4, 19, 20, 16]. The unique properties of Si-NPs allow them to cope with agricultural damage that may occur through climate change and/or abiotic stress (Tripathi *et al*. 2012) [23]. The application of Si-NPs in agriculture may also lead to global food security by helping in the development of improved varieties with high productivity (Parisi *et al*. 2015) [15]. Silicon nanoparticles are promising and have agricultural implications, and several new applications are being investigated for plants. In the agricultural sector, Si-NPs were observed to be applied as a weapon against heavy metal toxicity (Cui *et al*. 2017) [5], UVB stress (Tripathi *et al*. 2017) [22], salinity stress (Abdel-Haliem *et al*. 2017) [2], dehydration (Jullok *et al*. 2016) [9], etc. Moreover, additional novel applications of Si-NPs include their use as fertilizers, pesticides, and herbicides. Therefore, Si-NPs have the potential to improve crops for sustainable agriculture.

MgONPs

Magnesium (Mg) is an essential mineral element for plants and is nontoxic to organisms. To systematically investigate the antibacterial mechanisms of magnesium oxide nanoparticles (MgONPs) against the phytopathogen *Ralstonia solanacearum* (*R. solanacearum*) *in vitro* and *in vivo* for the first time. *R. solanacearum* has contributed to catastrophic bacterial wilt, which has resulted in the world-wide reduction of tobacco production. The results demonstrated that MgONPs possessed statistically significant concentration-dependent antibacterial activity, and the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were measured. MgONPs had exerted a large effect on tobacco bacterial wilt, reducing the bacterial wilt index. Altogether, the results suggest that the development of MgONPs as alternative antibacterial agents

Conclusion

Metal Oxide Nano particles (MONPs) consider a novel key to growing agricultural production through implementing nutrient efficiency, improve plant protection practices, also,these MONPs may have real solutions for various agriculture problems like improved crop varieties, plant protection, detect diseases and monitor plant growth. MONPs offers generous visions for the development agricultural sector through advanced applications and the probability of products and increases global crops production volume to feed the world population in next decades. Promising results and applications are already being developed in the areas of nano nutrients, implement crop productivity, protect plants (herbicides and pesticide), nano-packing and Nano sensors. In this study, Metal oxide nano particles exhibited superior antibacterial properties at an exceedingly low concentration compared to bulk metal oxide, which could prevent diseases in the host plant. The antibacterial activity of the metal oxide nano particles displayed significant concentration-dependent inhibition. Furthermore, the Metal oxide nano particles were adsorbed and dispersed on the bacterial cell walls, leading to destruction or disintegration of the cell walls, and then penetrated the bacterial cells, leading to leakage of the intracellular contents, which eventually resulted in cell death. In addition, the production of DNA fragmentation and genotoxicity was probably connected with the reactive oxygen. The suppression of the swimming motility and twitching motility may indicate that the nanoparticles also decreased the biofilm formation, greatly reducing the bacterial infection of the host plants. In summary, we expect that can present metal oxide nano particles a promising alternative as antibacterial agents and can be extended to other phytopathogens in potential applications for controlling plant diseases in the future.

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