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APPROACH FOR NANO-PARTICLE SYNTHESIS: USING AS NANO-FERTILIZER

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Abstract: The synthesis of nano-particles has become a matter of great interest in recent years due to their so many functional properties and applications in the variety of fields. Development of reliable and eco-friendly approach for synthesis of nano-particles is an important stage in the field of agriculture. The application of various nano-particles in plants has generated significant interest in agriculture nanotechnology. The impact of different nano-particles on the growth and metabolic functions diverge differently among plants. Nano-particle mediated fertilizers have the potential to enhance plant growth and soil fertility. The delivery of nano-fertilizers to the plants provides some insights for the improvement of the crop. The present paper reports the approach for nano-particle synthesis using as nano-fertilizer.

Keywords: Nanotechnology, Synthesis, Nano-particle, Fertilizer, Plant.

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INTRODUCTION

Nanotechnology is the manipulation, integration or self-assembly of individual atoms, molecules, or molecular clusters into complex to create material with new and extremely diverse properties. “Nano” suffix usually refers to a size scale between 1-100nm in dimension (Tarafdar and Raliya 2012). These particles have high surface to volume ratio and a high fraction of surface atoms. At nano level nanostructures have specific physiochemical properties, e.g., optical property, magnetic property, catalytic property. The applications of this knowledge in diverse field including, physics, chemistry, biology and engineering have been already utilized (Jain et al. 2011).

Nano-particles are submicron moieties (1-100nm) made of inorganic or organic materials. They have many unique features compared with the bulk materials. In this recent time, nano-particles have become a matter of great interest due to their different functional properties. According to their exclusive physical, chemical, thermal, and mechanical properties, and also by having suitable surface characteristics, nano-particles offer a great potential in many applications, such as cellular therapy, tissue repair, drug delivery, magnetic resonance imaging (MRI), hyperthermia, agricultural sector and environmental remediation. Currently, a large number of physical, chemical, biological, and hybrid methods are available to synthesize different types of nano-particles. Synthesis of nano-particles with their specific properties makes use of environmental friendly, non-toxic and safe reagents.

Application of nanotechnology in agricultural sector was one of the available choices to enhance the agricultural production, solve environmental problems, and feed the world’s growing population (Lal, 2008).The excessive use of chemical fertilizers in agriculture, generate several by-products which are toxic to ecosystems and also for environment. So, there is a requirement to develop a low-cost, eco-friendly method for agriculturally useful nano-particles. These applications include reducing the volume of pesticide use through the addition of nano-silver particles to pesticides to make them more effective in targeting pests with a smaller pesticide volume, adding nano-metal oxides to target soil pathogens. For instance, addition of nano-silicon to increase water uptake efficiency in plants, developing a DNA-based nano-biosensor in a polymer to coat fertilizers, which would release only as much fertilizer as “demanded” by plant root ionic signals. Each of these applications shows its own opportunities, risks, hopes and knowledge gaps. The use of nano-particles as a fertilizer in agriculture could, on the one hand, decrease cost and effort, increase efficiency and lead to more environmental friendly applications.

NANO-FERTILIZER:

Fertilizer delivery to plants is like drug delivery system for human being and animals. Fertilizers are material that provide nutrients to plants and also improve soil fertility. They are the most productive way of promote crop production and to upgrade the quality of food. Fertilizers help to increase plant growth by providing boosts of the much-needed macronutrients N, P and K to the plant, as well as other nutrients. But plants do not get the chance to use more than half of the nutrients in fertilizer because the compounds escape through leaching. For example, greenhouse gas emissions and hypoxia are just two of the negative environmental effect of the too much application of chemical fertilizers for major crops. Hypoxia is the scientific word for a "dead zone" area in a body of water, nearly deprived of oxygen as the outcome of agricultural water runoff carrying nitrates and phosphorus from fertilizer, e.g., the 6-7,000 square mile dead zone in the Gulf of Mexico. The usage of nanotechnology could lead to the solution of such problems. The use of a variety of plant materials for the biosynthesis of nano-particles is considered a green technology because it does not involve any harmful chemicals (Mahdavi et al. 2013).

For the tech-savvy farmer or gardener, nano-fertilizer could soon solve the problem of nutrient depletion and environment. Molecular modified materials which are synthesized with the help of nanotechnology, used to amend the soil for a better yield and enhance crop quality and quantity, are called Nano-fertilizers. Nano-fertilizers are substance that release nutrients as plants need them. Nano-science has found utilization in controlling the release of nitrogen, characterization of soil minerals soil development, nature of soil and nutrient ion transport in soil-plant system. Nanotechnology has accelerated new ways to boost nutrient efficiency and minimize costs of environmental safety. Nano-fertilizers could be applied to reduce nitrogen loss as leaching, emissions and long-term incorporation by soil microorganisms. Because of the slow and controlled discharge of fertilizers soil become better by decreasing toxic effects relates with fertilizer over use.

IMPECT OF NANO-FERTILIZER ON AGRICULTURE:

Using nano-fertilizer to control delivery of nutrients can be a powerful tool towards attaining sustainable agriculture and environment. Nano-fertilizers with quick absorption and optimized release of nutrients to the plant are going to replace conventional fertilizers. Still little progress has been made respecting the use of nano-particles to improve soil quality and to reclamation disturbed lands. Nano-fertilizers, crop yields and greenhouse gas emissions among the technologies whose followers claim to raise crop yields while reducing the environmental damage of agriculture. Possibly no claim is more appealing than increasing the efficiency of fertilizers and reducing the negative environmental effects due to chemical fertilizers through nanotechnology. Agricultural plants needs optimized managements as well as appropriate weather and soil condition for maximum usage of environment potentials and therefore best performance. Production of inorganic materials from biological systems such as plants and microorganisms, which are present in nano-scale dimensions. The cellular extracts from these organisms can be used to synthesize nano-particles with different size, properties and chemical compositions. Biosynthesis of metal nano-particles can be squeezed from distinct parts of the plant is the best efficient method of synthesis at a very low cost (Pattanayak and Nayak 2012).

Usage of Different Nano-particles as Fertilizer: Implement of nanotechnology in agriculture through fertilizer modification is one of the possible choices to increment in the crop production and feed the world's increasing population. The rising nano-strategies signify that due to the high surface area to volume ratio, nano-fertilizers would be a revolution in the agricultural field.

Phosphate-Based Nano-particles as Fertilisers: Phosphorus is an important nutrient and phosphate based nano-particles have capacity to be used as P-nano-fertilizer for agriculture use. These are applicable for heavy metal remediation by forming highly insoluble and stable phosphate compounds (Liu and Lal 2012). Vivianite ($Fe_3(PO_4)_2 \cdot 8H_2O$) particles (~10nm) and apatite ($Ca_5(PO_4)_3Cl$) particles (<200nm) are phosphate based nano-particles. Vivianite nano-particles synthesized with sodium carboxymethyl cellulose (CMC) as a stabilizer for in situ immobilization of lead in soils. Vivianite can effectively reduce the TCLP (toxicity characteristic leaching procedure) leach-ability and PBET (physiologically-based extraction test) bio-accessibility of Pb^{2+} in calcareous, neutral, and acidic soils. Compared to soluble phosphate used for in situ metal immobilization, use of the vivianite result in 50% decline in phosphate leaching into the environment (Liu and Jhao 2007).

Nitrogen Based Nano-particles as Fertilisers: Nitrogen is a key nutrient source for biomass production in agriculture and most important element in fertilisers. Conventional fertilisers, with particle size dimensions greater than 100nm. These are missing to the soil via leaching, emission as ammonia and nitrogen oxides, and soil microorganism-mediated incorporation into soil organic matter over time. Nowadays, the emerging nano-strategies point out that, due to the high surface area to volume ratio, nano-fertilizers are expected to be far more effective than even polymer-coated conventional slow-release fertilisers. A nano-strategy involving a slow-release fertilizer combination based on urea-modified hydroxyl-apatite (HA) nano-particles encapsulated into the cavities exist in soft wood. HA ($Ca_{10}(PO_4)6(OH)_2$) nano-particles are rated as one of the outstanding candidates in agricultural applications, which can supply phosphorus nutrient (Nilwala et al. 2011).

Iron Based Nano-particles as Fertilizers: Iron is the metal used at the active site of many essential redox enzymes dealing with cellular respiration and oxidation reduction in plants and animals (Tarafdar and Raliya 2013). Iron is abundant in soil and its compounds make up to 5% of earth crust weight (Talaei 1998). In spite of large amount, due to it less accessibility its shortage is common for plants. Most of present iron is insoluble. Only a small amount of iron is soluble ($Fe(OH)_2$, $Fe(OH)^{+2}$, Fe^{+3}, Fe^{+2}). Iron is a crucial element for growth of plants, lack of iron causes chlorosis and significantly reduction in photosynthesis activity and consequently biomass produced (Briat et al. 2007). Iron chelate nano-fertilizer can be recognized as a rich and decisive source of bivalent iron for plant because of its high stability and slow release of iron in a broad pH range (3-11). Absence of ethylene compounds in its structure is a benefit of this nano-fertilizer. Ethylene enhances growth progress and restricts chlorosis leaves. Second advantage of these nano-fertilizers is increasing ratio of ferrous iron to ferric iron in chelate surface which results in increasing synthesis of chlorophyll in plant (Hokmabadi et al. 2006; Moghadam et al. 2012).

Zinc Based Nano-particles as Fertilizers: Zinc deficiency has been identified as one of the main problem limiting agricultural productivity in alkaline calcareous soils. Thus, zinc is often included in macronutrient fertilizers to enhance crop production and quality. The addition of zinc fertilizers to soil, zinc transforms gradually from more active and available fractions into less available species such as precipitates (i.e., ZnCO3) and adsorbs to oxide phases (e.g., Fe-, Al-oxides). Moreover, availability of zinc to plants in calcareous soils mainly depends on the diffusion of zinc from fertilizer granules to the plant root. Nano-materials could be applied in designing more soluble and diffusible sources of zinc fertilizer for increased plant productivity. The smaller size, higher specific surface area and reactivity of nano-particulate ZnO compared to bulk ZnO may affect zinc solubility, diffusion and hence availability to plants.

Titanium Based Nano-particles as Fertilizers: The nano TiO_2 (anatase) improved light absorbance and promoted the activity of rubisco activase thus accelerated plant growth (Hong et al. 2005; Gao et al. 2006; Lei et al. 2007; Gao et al. 2008). Anatase improved plant growth by enhanced nitrogen metabolism and accelerating conversion of inorganic nitrogen into organic nitrogen, thereby fresh weights and dry weights increase. Effects of anatase on the content of light harvesting complex II on thylakoid membranes showed an increase in LHC II content (Lei et al. 2007). These promote energy transfer and oxygen evolution in photo-system II. It has also been found that anatase promoted antioxidant stress by decreasing the accumulation of superoxide radicals, hydrogen peroxide, malonyldialdehyde content and enhance the activities of superoxide dismutase, catalase, ascorbate peroxidase, guaiacol peroxidase. The ability of anatase to improve the light harvesting complex content of plants is highly comparable with the use of TiO_2-quantum dot (QD) assembly for the conversion of solar energy (Kongkanand, 2008). Uptake and distribution of QD by the plant cells can be exploited for increased solar energy trapping that might improve the photosynthetic efficiency of plants.

Aluminum Based Nano-particles as Fertilizers: Nano-aluminum has been used in various industries and hence there is great chance for the interaction of such nano-materials with higher plant that constitutes a major portion of the ecosystem. Pure alumina nano-particles (13nm) without any modifications reduced root elongation in various plants like, *Zea mays, Cucumis sativus, Glycine max, Daucus carota* and *Brassica oleracea* thus potentially retarding the growth of plants (Yang and Watts, 2005). However, it was surprisingly observed that when nano-particles were loaded with phenanthrene (polycyclic aromatic hydrocarbons) their toxicity significantly decreased showing no adverse effects on roots of plants. This showed the relevance of proper surface modifications which reduce the phyto-toxicity of nano-particles. The impact of aluminum oxide and aluminum oxide with carboxylate ligand coating particles (100nm) on plants shows no adverse effect on the growth (Doshi et al. 2008). Aluminum concentration in rye grass was increased 2.5-fold above control tests whereas no uptake of aluminum was observed in kidney beans which inferred the difference in uptake and distribution efficiency of even the same kind of nano-particles by different plants.

Copper Based Nano-particles as Fertilizers: The seed germination in the presence of Cu NPs showed an increase in shoot to root ratio compared to control plants (Shah and Belozerova 2009). Different flora and fauna gives versatility in their response to nano-particles. It is necessary to evaluate the secure effective concentration of each group of nano-particles before their application that lower the risks of eco-toxicity to a very large extend.

Silver Based nano-particles as Fertilizers: Silver nano-particles have antimicrobial properties to control various phyto-pathogens (Jo and Kim 2009; Park et al. 2006; Min et al. 2009; Kim et al. 2009). Effect on the seed germination and root growth of plants in hydroponic solution enhanced with Ag NPs showed no negative effects. On the other side a decrease in plant biomass and transpiration was observed on prolonging their growth in presence of Ag NPs (Stampoulis 2009). The cytotoxic and genotoxic impacts of Ag NPs were analyzed with root tips of onion. It was observerd that Ag NPs impaired the stages of cell division and caused cell disintegration (Kumari 2009). These results show the requirement for a more cytotoxic and genotoxic evaluations by considering the properties of nano-particles, their uptake, translocation and distribution in different plant tissues.

ACHIVEMENTS OF NANO-FERTILIZERS

Enhancement in fertility and the instinct of self-preservation greatly enhance the productivity, quality and reliability of a crop. This translates into an improvement to three major areas of production:

1. Yields: Nano-fertilizers increase yields by an average of 20%, and for some crops even more. This composite number implies growth in leaf, biomass, fruit and grain separately. For example, in some experiments sunflower grain yields increased by 50% and in cucumber trials yield increases up-to 25% have been observed.

2. Nutritional Value: Results showed an increasing effect of about 10% in both protein and sugar content of treated plant for most types of crops plant.

3. Health: Overall health of the plant is enhanced, making it more resistant to severe weather and extreme environmental conditions. Immunological response is allowing the plant to fight

with disease and prevent infections.

CONCLUSION

Application of nanotechnology in agriculture, even at its global level, is at its primary stage. Nano-science is leading to the development of a range of low cost nano-technological applications for increased plant growth. Nano-particles and nano-capsules provide an efficient means to distribute pesticides and fertilizers in a controlled fashion with high site specificity reduce the collateral damage. Following facts could be started about the usage of nano-fertilizers:

1. Nano-fertilizers are advantageous over conventional fertilizers as they increase soil fertility and crop quality.
2. They are non toxic and less harmful to environment and humans as compared to conventional ordinary fertilizers.
3. They minimize cost and maximize profit because they are used in very small quantities.
4. It is just the beginning of a new advanced era and there is a great need of agricultural technique modification to fulfil the requirement of upcoming generations.

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