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EFFECT OF NANOPARTICLES ON PLANT GROWTH AND PHOTOSYNTHESIS

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ABSTRACT

*Nanoparticles are now being used in all facets of modern life. In this scenario the effect of nanomaterials must be studied not only in animal systems, but plant world should also be examined for the nanoparticle exposure. It was found that many nanomaterials have beneficial effect on plant system as they help in seed germination and over all plant growth. It was also found that many nanoparticles can enhance the photosynthetic rate of plants. Specifically Plasmon resonance of metal nanoparticles can enhance the absorption of light energy and ultimately cause the enhancement of photosynthetic rate. We studied the effect of gold nanoparticles, surface functionalized with three different capping agents on mung (*Vigna radiata*) plant. All the gold nanoparticles were found to augment plant growth and photosynthesis.*

Keywords: Nanobionics, Surface Plasmon Resonance, Gold nanoparticle, Surface functionalization, Vigna radiata

Photosynthesis is the main source of energy for life on earth. The entire life either directly depends on photosynthesis for their source of energy or indirectly as ultimate energy currency in their food (Nealson and Conrad. 1999). If we go through the stoichiometry, approximately 100 terawatts energy is captured by photosynthesis (Whitmarsh and Govindjee 1999) from sunlight that is nearly six times greater than the power consumption need of human civilization (Steger et al. 2005). The process converts carbon dioxide into organic compounds, broadly sugars, utilizing the energy from sunlight (Bryant et al. 2006). Photosynthesis occurs with the interaction between two sets of reactions: light dependent reactions where energy acquired from sunlight and utilizes it to make energy storage molecule ATP and NADPH. Another stage is light independent and it involves the product of light reaction to capture and reduce carbon dioxide.

Nowadays nanotechnology is being used in almost every facet of modern life. In this scenario we have to be concerned about the effect of these nanomaterials not only in animal system, but also in the plant world. The key questions which need to be addressed are - what degree of nanoparticles (NPs) is uptaken by plants and what their effect is on plant development? Though the effect of NPs on plant growth or photosynthesis varies from plant to plant, there are few reports on the effect of nanomaterial on plant growth and photosynthesis. Researchers have found that application of nanosilica can make paddy plants strong, disease resistant and thus is responsible for more yield of rice. Wang et al. (1999) also reported the advantageous effect of nanomaterial on plant growth. Another research group working on carbon nanotube (CNT) observed that CNT can penetrate seed coat and thus improve water supply in tomato seeds leading to dramatic increment of seed germination and plant growth (Khodakovskaya et al. 2009). Now there are several scientific studies on effect of NPs on plant

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photosynthesis. Hong et al. (2005) worked on the effect of nano-TiO_2 on photosynthetic efficiency of spinach. Their research suggested that nano-TiO_2 can enhance light absorbance, accelerate transport and transformation of light energy and can prolong the effective photosynthetic tenure of chloroplasts by protecting the chloroplasts from ageing. Manganese NPs were also found to be efficient in enhancing the photosynthetic electron transport rate and oxygen evolution in *in vitro* model system (Pradhan et al. 2013). Photosynthetic rate was found to be increased when iron oxide NPs were sprayed foliarly on soybean plants (*Glycine max*). This increase in photosynthetic rates was attributed to increases in stomatal opening (Alidoust et al. 2013). In a recent study ZnO NPs were noticed to be responsible for reduction of photosynthetic efficiency of *Arabidopsis.* Probably ZnO NP mediated inhibition of the expression of chlorophyll synthesis genes and photosystem structure genes, resulted in the inhibition of chlorophylls biosynthesis, and this ultimately caused reduction in photosynthesis efficiency in *Arabidopsis* (Wang et al. 2016). Carbon nanotubes also can enhance the light reaction rate of photosynthesis (Giraldo et al. 2014).

Strong enhancement of electromagnetic fields generated through plasmon (the electron cloud around the metal atom) resonances in metal films and in nano particulate form has in recent times stimulated a considerable interest in diverse research fields such as photobiology and photosynthesis. Plasmon-induced amplification of electromagnetic fields inside the artificial photosynthetic reaction centre can dramatically enhance both emission and absorption of a peridinin-chlorophyll-protein photosynthetic antennae complex Mackowski et al. (2007). Their studies showed that presence of metal NP can increase chlorophyll fluorescence 18 fold. Govorov and Carmeli (2007) from Ohio University and Tel Aviv University reported that metal NP bound to chlorophyll molecule of a hybrid photosynthetic reaction centre can produce 10 times more excited electrons due to Plasmon enhancement effect.

Photosynthesis is photo catalyzed and enzyme catalyzed chemical reaction. Since the plasmon effect can increase the generation of electrons inside the photosynthetic complex, metal NPs should enhance the absorption of light energy, transforming light energy into chemical energy, electron transport rate, oxygen evolution rate and photophosphorylation activity etc. So we studied the effect of three different gold NPs (GNPS) of similar size but with different surface functionalities (aspartate, BSA and citrate capped) on light dependent photosynthetic reaction that mainly involves the production of energy storage (ATP and NADPH) for light independent reactions. Further we studied the effect of these GNPs on primary growth of plant. The plant model system used was mung (*Vigna radiata)*.

According to our experimental data it was evident that these three GNPs of similar size were effective in augmenting the rate of photosynthesis and growth of plant but their efficacy was not completely identical. Amongst three, citrate capped GNP had the most significant and advantageous effect in photosynthesis enhancement and growth promotion of mung (*V. radiata*).

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