Reducing Strength Prevailing at Root Surface of Plants Promotes Reduction of Ag^{+} and Generation of Ag^{0}/Ag_2O Nanoparticles Exogenously in Aqueous Phase

Peddisetty Pardha-Saradhi[1]*, Gupta Yamal[1,2], Tanuj Peddisetty[3], Peddisetty Sharmila[4], Shilpi Nagar[1], Jyoti Singh[5], Rajamani Nagarajan[5], Kottapalli S. Rao[2]

1 Department of Environmental Studies, University of Delhi, Delhi, India, **2** Department of Botany, University of Delhi, Delhi, India, **3** Department of Petroleum Engineering & Earth Sciences, University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India, **4** Department of Chemistry, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India, **5** Department of Chemistry, University of Delhi, Delhi, India

Abstract

Potential of root system of plants from wide range of families to effectively reduce membrane impermeable ferricyanide to ferrocyanide and blue coloured 2,6-dichlorophenol indophenol (DCPIP) to colourless $DCPIPH_2$ both under non-sterile and sterile conditions, revealed prevalence of immense reducing strength at root surface. As generation of silver nanoparticles (NPs) from Ag^{+} involves reduction, present investigations were carried to evaluate if reducing strength prevailing at surface of root system can be exploited for reduction of Ag^{+} and exogenous generation of silver-NPs. Root system of intact plants of 16 species from 11 diverse families of angiosperms turned clear colorless $AgNO_3$ solutions, turbid brown. Absorption spectra of these turbid brown solutions showed silver-NPs specific surface plasmon resonance peak. Transmission electron microscope coupled with energy dispersive X-ray confirmed the presence of distinct NPs in the range of 5–50 nm containing Ag. Selected area electron diffraction and powder X-ray diffraction patterns of the silver NPs showed Bragg reflections, characteristic of crystalline face-centered cubic structure of Ag^{0} and cubic structure of Ag_2O. Root system of intact plants raised under sterile conditions also generated Ag^{0}/Ag_2O-NPs under strict sterile conditions in a manner similar to that recorded under non-sterile conditions. This revealed the inbuilt potential of root system to generate Ag^{0}/Ag_2O-NPs independent of any microorganism. Roots of intact plants reduced triphenyltetrazolium to triphenylformazon and impermeable ferricyanide to ferrocyanide, suggesting involvement of plasma membrane bound dehydrogenases in reduction of Ag^{+} and formation of Ag^{0}/Ag_2O-NPs. Root enzyme extract reduced triphenyltetrazolium to triphenylformazon and Ag^{+} to Ag^{0} in presence of NADH, clearly establishing potential of dehydrogenases to reduce Ag^{+} to Ag^{0}, which generate Ag^{0}/Ag_2O-NPs. Findings presented in this manuscript put forth a novel, simple, economically viable and green protocol for synthesis of silver-NPs under ambient conditions in aqueous phase, using root system of intact plants.

Citation: Pardha-Saradhi P, Yamal G, Peddisetty T, Sharmila P, Nagar S, et al. (2014) Reducing Strength Prevailing at Root Surface of Plants Promotes Reduction of Ag^{+} and Generation of Ag^{0}/Ag_2O Nanoparticles Exogenously in Aqueous Phase. PLoS ONE 9(9): e106715. doi:10.1371/journal.pone.0106715

Editor: Vipul Bansal, RMIT University, Australia

Received December 31, 2013; **Accepted** August 9, 2014; **Published** September 3, 2014

Funding: Yamal and Shilpi thank Council for Scientific and Industrial Research (Govt. of India) for providing research fellowship. Sharmila thanks the Department of Biotechnology (Govt. of India) for financial support under Bio-CARe Women Scientist Scheme. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

* Email: ppsaradhi@gmail.com

Introduction

Nanotechnology has witnessed spectacular advancement in fabrication and utilization of nanomaterials. Owing to small size and large surface to volume ratio, nanoparticles possess unique physicochemical and biological properties which differ entirely from the bulk material. Amongst different metal nanoparticles, the synthesis and application of silver NPs received wide attention, as silver nanoparticles find application in almost every sphere of life. Due to immense antimicrobial properties, silver NPs find wide application in medicine especially artificial teeth, bone coating, medical catheters, wound dressings besides surgical instruments. Silver nanoparticles are also extensively used in daily commodities such as cosmetics (viz. lotions, creams etc.), toothpastes, detergents, soaps, surface cleaners, room sprays, shoe insoles and textiles. Utility of silver nanoparticles in home appliances (such as washing machines, air and water filters), automotive upholstery, paints and food storage containers is also known [1–4]. Silver NPs find usefulness in sensing applications such as biolabeling, optical imaging of cancer and detection of DNA sequences [5,6]. Electronic application of silver nanoparticles includes its usage for the preparation of optical devices, inks for circuit boards, high density recording devices, battery-based intercalation materials [6–9]. Large surface area of silver NPs provides high surface energy for catalysis [10]. Silver NPs of different sizes and shapes are routinely synthesized by various chemical and physical methods [11–13]. Various physical, chemical and physico-chemical approaches such as ion sputtering, laser ablation, inert gas condensation, mechanical milling, thermal or laser irradiation, chemical reduction, sol-gel technique, photochemical reduction and electrochemical techniques have so far been employed to generate metal NPs [12–14]. The Lee-Meisel method using sodium citrate along with heating for 1 h for generation of silver nanoparticles continues to be the standard by which other