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Root system of live plants is a powerful resource for the green synthesis of Au-nanoparticles†

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Sixteen plant species from 11 distinct families were evaluated for their potential to exogenously fabricate Au-nanoparticles (NPs) at the root surface. The root system of intact plants of all species turned clear pale yellow colloidal salt solutions of Au purple/golden. Transmission electron microscopy coupled with energy dispersive X-ray spectroscopy revealed the presence of Au-NPs in the range of 5–100 nm in these colloidal solutions. PXRD showed the crystalline nature of Au-NPs. Reduction of 2,6-dichlorophenol-indophenol (DCPIP) by the root system of intact plants confirmed that the root surface possesses the strong reducing strength necessary for the reduction of Au^{3+} to Au^0 and to generate Au-NPs. Our findings unequivocally demonstrated for the first time that roots of intact plants of certain species can be exploited for the bulk synthesis of Au-NPs exogenously under ambient conditions in an aqueous phase. These findings highlight a novel, simple, economically feasible and green/eco-friendly scheme for the exogenous production of Au-NPs in an aqueous phase under ambient conditions.

Owing to their unique physical and chemical properties, metal nanoparticles (NPs) find application in innumerable sectors of engineering including aerospace and defence, medicine, environment and agriculture.[1–3] Gold (Au) on the nanoscale possesses unique physical and chemical properties which made it an object of interest amongst chemists, physicists, and even biomedical practitioners.[4] Such unique properties make Au-NPs well suited for key materials and building blocks for nanodevices, and various applications ranging from catalysis, to diagnostics, to separation science.[4–7] Au-NPs synthesized/grown in an aqueous phase are of immense importance in biological applications such as drug delivery, cancer therapies, gene transfer and recognition, biological markers *etc.*[4,8,9]

Au-NPs of different sizes and shapes are routinely synthesized by various chemical and physical methods.[6,10] Unfortunately, these synthetic approaches have limitations and a negative impact on the environment and human health.[11,12] Therefore, there has been a constant urge across the globe to develop an ideal green protocol, alternate to current physical or chemical method(s) for the synthesis of Au-NPs. In an urge to develop green methods for the synthesis of Au-NPs, researchers have made an effort to use biological systems. These so far largely encompass, the use of microorganisms, biomass of microorganisms and plants, cell free extracts of microorganisms and plant materials.[1,13,14]

Another approach that is being popularized by a few research teams is the intracellular synthesis of Au-NPs in various parts of live plant species *viz. Sesbania drummondii*, *Brassica juncea*, *Medicago sativa*.[15–17] However, extraction of intracellularly formed Au-NPs from plants for commercial application would be unfeasible.

To the best of our knowledge, to date no research team has made any effort to evaluate whether plants have the potential to generate Au-NPs exogenously at their root surface. The exogenous fabrication of Au-NPs would be advantageous as downstream processing would be less laborious.

For generating Au-NPs, 16 plant species (Table 1) belonging to 11 diverse taxonomic families of angiosperms were collected from distinct habitats/conditions, namely, natural conditions (*i.e.*, growing in the wild), maintained garden beds and controlled conditions (grown in sterile and non-sterile conditions in a laboratory). For detailed methodology see the ESI.†

For evaluating the potential of the root system of intact plants to generate Au-NPs, they were exposed to different concentrations (*viz.* 0.01, 0.05, 0.1, 0.25, 0.5, 1 and 2 mM) of hydrogen tetrachloroaurate trihydrate ($HAuCl_4 \cdot 3H_2O$) prepared in sterile double distilled water. The plants were incubated at

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