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RESEARCH ARTICLE

RECYCLING OF HYPERACCUMULATOR PLANTS IN SYNTHESIS OF NANOPARTICLES: GREEN TECHNOLOGICAL APPROACH

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ABSTRACT

The metal accumulating ability of plants (hyperaccumulators) has previously been used to detoxify and environment clean up of metal contaminants from different site. However, the full potential of this process is now being explored via reuse of these hyperaccumulators in nanotechnological practices. This short review article is devoted to the ability for hyperaccumulator plants to form metallic nanoparticles by reusing the toxic metal accumulated in these plant for their positive utilization in novel nanoparticle synthesis. This approach inspires the search for new strategy of eco-benign, cost effective way on the synthesis of nanoparticle by using non renewable cost effective, eco-sustainable resources.

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INTRODUCTION

In modern nanotechnology one of the most exciting areas of research is the biosynthesis of metal nanoparticles through the biological resources. Synthesizing nanoparticles via unicellular and multi-cellular biological entities i.e., micro-organism (Salunke *et al*., 2014), fungus (Ahmad *et al*., 2005), yeast (Agnihotri *et al*., 2009), algae (Castro *et al*., 2013) and plants (Salunke *et al*., 2014; Philip, 2010) is environmentally acceptable as it offers a clean, nontoxic, cost effective better alternative compared to chemical/ and or physical method of nanopartical synthesis. Synthesizing nanoparticle via plant resources is suggested to be more advantageous since it does not need any special, complex, and multi-step procedures such as isolation, culture preparation, and culture maintenance (Iravani, 2011). Furthermore, synthesis in plants tends to be faster than microorganisms, is more cost-effective and is relatively easily available resource for the production of large quantities of nanoparticles (Kumar *et al*., 2009). Heavy metals are hazardous and dangerous, especially when introduced into the environment via pollution. However, heavy metal nanoparticles are used in various nanoscience and nanotechnology applications.

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Some plants have high potential to hyper-accumulate toxic metal ions and biologically reduce metallic ions into nanoparticle form in their tissue through metabolic reactions (Kulkarni and Muddapur, 2014). Because of these interesting properties, plants have been considered, a more environment-friendly route for biologically synthesizing metallic nanoparticles and for detoxification applications of metal contaminants. It has been depicted that many plant species have inherent capacity to actively uptake and bio-reduce metallic ion from soil and solutions through their specific metabolic pathway that result in the assembly of insoluble complex with metal ion in form of useful metallo-organic nanocrystal structures (Iravani, 2011).

This phenomenon of metal detoxification in hyperaccumulator plants attracts the phyto-remediation researchers to develop the eco-benign route of transformation of toxic metallic resources in plants in phytosynthesis of metal nanoparticles. Plant bioactive metabolites such as alkaloids, polyphenols, proteins, sugars, and terpenoids play an important role in reducing the metallic ion and transforming into nanoparticle (Shah *et al*., 2015). This process offers a new, environmentally friendly method of producing metal nanoparticles as well as recycling of hyperaccumulator plants (Anderson, 2013). Hyper accumulator plants are largely used in phytoremediation and phytomining due to its ability to sequester metals from the

Table 1. Use of hyperaccumulator plants in phytosynthesis of metallic nanoparticles

S. No.	Hyperaccumulator plant species	Metal accumulated	Synthesized nanoparticle	Reference
1	*Brassica juncea*, *Helianthus annus*, *Medicago sativa*	Ag, Cu, Co, Zn and Ni	Ag, Cu, Co, Zn and Ni	Bali *et al*. (2006)
2.	*Brassica juncea*	Ag	Ag nanoparticle	Haverkamp and Marshall (2009)
3.	*Sedum alfredii*	Zn	ZnO nanoparticles	Qu *et al.* (2011a)
4.	*Physalis alkekengi* L.	Zn	ZnO nanoparticle	Qu *et al.* (2011b)
5.	*Medicago sativa* L.	Au	Au nanoparticles	Gardea- Torresday et al. (2012)
6.	*Eichhronia crassipes* L.	Pb, Cu, Zn, Cr, Cd	Pb, Cu, Zn, Cr, Cd nanoparticles	Mahmood et al. (2012)
7.	*Brassica juncea* L.	Cu	Carbon nanotubes Cu/ZnO nanoparticles	Qu *et al.* (2012)
8	Brassica juncea *L.*	Cu, Zn	carbon nanotubes (CNTs), $Cu_{0.05}Zn_{0.95}O$ nanoparticles, and CNTs/$Cu_{0.05}Zn_{0.95}O$ nanocomposites	Qu *et al.* (2013)
9.	*Physalis alkekengi* L.	Zn	Carbon nanotubes (CNT), ZnO nanoparticle & nanocomposites	Cong *et al.* (2014)
10.	Astragalus bisulcatus L.	Se	Se nanoparticles (SeNPs)	Lampis *et al*. (2014)

environment and it can be regarded as a low-cost, eco-friendly and efficient approach for the cleanup of metal polluted sites (Terry and Zayed, 1998). Though, metals in hyperaccumulator plants are good resource and reuse of these metals in nanoparticle formulation is more feasible and significant (Haverkamp and Marshall, 2009). Such an approach offers innovative new ways, where plants are used to treat heavy metal waste effluents and renewed it to nanoparticle formulation. The formation of nanoparticles was first reported by Gardea- Torresdey *et al*. (2002) in gold hyperaccumulator alfalfa plant.

They used this plant in phytomining of gold from mine ores and leachates and used it in synthesis of gold nanoparticle in cost-effective way. Various research and review papers deal with the phytoremediation of toxic metals by hyperaccumulating plants and the production of metal nanoparticles (Qu *et al*., 2011, 2012, Mahmood *et al*., 2012) (Table 1). The phytosynthesis of nanoparticles using a hyperaccumulator plants have positive aspects in eco-sustainability both in solving the recycling of hyperaccumulator plants as well as replacing the toxic metal of plant into useful nanocomposite products.

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