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Green silver nanoparticles: An expert solution to many problems of agriculture

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INTRODUCTION

Nanotechnology is an emerging field of technology that amalgamates the knowledge of different disciplines of sciences and engineering, to produce materials which have potential to revolutionise the world. “Nano” is a Greek word meaning extremely small and the term “nanoparticals” refers to group of atoms of 1 – 100 nm in size (Vadlapudi and Kaladhar, 2014). Couvreur (1988) described nanoparticles as compact, colloidal particles having at least one dimension less than 100 nm. Nanoparticles, especially metallic nanoparticles, due to high surface to volume ratio possess extraordinarily low melting point, larger specific surface area, good optical properties and mechanical strength (Ge et al., 2014). Due to these properties nanoparticles find extensive applications in day-to-day life, including pharmaceutics, biosensors, cosmetics, food processing, precision engineering, precision agriculture and environmental sciences (Saxena et al., 2012). The nanoparticles also act as nanoantibiotics due to their antimicrobial properties (Sastry et al., 2003). Among all the metal-based nanoparticles, silver nanoparticles have most remarkable properties, especially the nanoparticles produced by green synthesis method.

The most common metals used for green synthesis of nanoparticles are Silver, Aluminium, Gold, Zinc, Iron, Titanium, Palladium and Copper (Vadlapudi and Kaladhar, 2014). Among these, silver nanoparticles are most significant due to stability, good catalytic and electrical activity and inhibition ability for large number of microbes (Sharma et al., 2009). Application of silver nanoparticles is also observed in water treatments, in textile industries and in many cosmetic products. Silver nanoparticles possess remarkable antimicrobial and ROS inhibiting property. Application of nanosilver is well documented in the field of medicine, horticulture, food packaging, cosmetics giving a new dimension towards innovation. The green silver nanoparticles, synthesized by biological methods are particularly useful.

Why Silver?

Silver nanoparticles are now in the centre of focus because of their unique attributes such as size, shape, optical, electrical (Chen et al., 2009) and magnetic properties. The unique property of silver nanoparticle arises due to its unique position in periodic table and different oxidation states. Silver (Ag) exhibit four oxidation state, two abundant states Ag^0, Ag^+ and Ag^{2+}, Ag^{3+} which are unstable in aquatic condition (Ramya, 2012). The metallic silver is insoluble in water, while salts are soluble in water. Silver is not carcinogenic and does not negatively affect immunity, reproductivity and cardiovascular system. This makes them excellent candidate for medical applications. The silver nanoparticles have a size range of 1-100 nm and have 20-15000 silver atoms (Williams, 2008).

Silver nanoparticles have gained importance in recent years particularly for medicinal use. However, use of silver for healing purposes is not new. Ancient Egyptians used silver powder for curing wound infection due to the its healing properties (Russel and Hugo, 1994). Silver nanoparticles show effective antimicrobial attributes. The Ag^+ ions present in the nanoparticles increases the membrane plasticity of the bacterial cell and forms pit in the membrane leading to Reactive oxygen species (ROS) production (Morones et al., 2005). The resultant oxygen deficiency causes the death of the bacteria. This property enables the use of silver nanoparticles in textiles (Perelshtein et al., 2008), plastics, electric appliances, different health care product and other products production.

Biological Synthesis

The physical, chemical and biological techniques are used for the synthesis of nanoparticles. The physical and chemical methods are not cost-friendly and lead to nanoparticles being toxic in nature; rendering the need of purification (Ahmed et al, 2015). On the other hand, nanoparticles produced using biological methods (known as green nanoparticles) are environment friendly since these methods utilize the natural extracts. The sugars, vitamins and biodegradable polymers present in plant, microbial and other biological extracts act as reductant and capping agents in the green synthesis method (Ahmed and Ikram, 2015). Among these, the synthesis using plant extracts have gained focus in recent years due to cost-effectiveness and ease of availability (Sithara et al., 2017). Because of environment-friendly nature, nano-particles synthesized by this method are widely accepted in commercial industries like pharmaceutical, nutrition, chemical and cosmetic (Rao and Tang, 2017).

For synthesis of silver nanoparticles, several methods *viz*. sparking, irradiation, electrochemical reduction and cryo chemical method are mostly employed. Biological methods, have also gained emphasis in recent years. Due to their simple process, these methods eliminate the need of complex chemical procedure and addition of extra stabilizing and capping agent from outside, since the natural reagents contain reducing agent and cell constituent which perform these tasks (Srikar et al., 2016). The fungal extract, bacterial extract or plant extract (Sorescu et al., 2016) are mostly used for green synthesis of nanoparticles. The plants like neem, tulsi, pepper, grapes, neem, olive and others have been used for the green synthesis of nanoparticles. The most common plant part used for the extract preparation is leaves, though stems, roots, seeds and entire plants have also been used for the preparation of extracts (Table 1). The aqueous or methanolic extract of these plant parts are used for the synthesis of silver nanoparticles ranging from size 2-880nm. The techniques like UV-Vis, XRD, TEM, FTIR, AFM, DLS, ZP, EDS and others are most commonly used to confirm the presence of nanoparticles.

Table: List of plants and their parts used in green synthesis of silver nanoparticles

S. No.	Part Used for extract preparation	Plants
1	Leaf	*Cycas, Acalypha indica, Catharanthus roseus, Eclipta prostrate, Piper betel L., Nelumbo nucifera, Azadirchata indica, Morinda citifolia L., Crossandra infundibuliformis, Ocimum tenuiflorum, Olive, Lxora coccinea L., Elaeagnus indica, Tephrosia purpurea, Plectranthus amboinicus, Withania somnifera, Couroupita guianensis, Ziziphora tenuior, Acacia senegal, Cassia auriculata, Morus alba, Flemingia wightiana*
2	Fruit	*Piper nigrum, Tanaetum vulgare, Citruslimon, Tribulus terrestris L, Vitis viniera, Kigelia Africana, Couroupita guianensis*
3	Entire plant	*Anthoceras, Trachyspermum ammi, Papavera somniferum, Codium captium, Myrmecodia pendan*
4	Mesocarp	*Cocos nucifera*
5	Stem	*Tinospora cordifolia*
6	Root	*Tinospora cordifolia*
7	Seed	*Pistacia atlantica*
8	Flower	*Cassia auriculata*

Application of silver nanoparticles in agriculture

Utilization of green silver nanoparticles for antimicrobial and insecticidal properties

Silver nanoparticles show biocidal properties (Toker et al., 2013). The nanoparticles of size less than 100 nm have better antimicrobial activity (Monores et al., 2005). Among all the metal ions used to prepare nanoparticles, silver nanoparticles show best result because of their large surface area since they can make surface contact with microorganisms (Rai et al., 2009). The silver nanoparticles disrupt cell division and respiratory chain causing death of the microbial cell (Monores et al., 2005). Nanosilver is found to be effective against both gram positive and gram-negative bacteria. Green silver nanoparticles produced using neem extract was found to be effective against both gram positive (*Staphylococcus aureus*) and gram negative (*E. coli*) bacteria (Ahmed et al., 2016). The silver nanoparticles prepared using apple extract were effective against *S. aureus*, *P. aeruginosa* and *E. coli* respectively (Ali et al., 2016). Silver nanoparticles have been found to be effective against bacterial and fungal pathogens of plants. They have also been found to be effective against insects. Silver nanoparticle at a concentration of 700 mg mL^{-1} was found to show same effect as 1 μL mL^{-1} imidacloprid against *Aphis nerii* and caused maximum insect mortality (Rouhani *et al.*, 2012).

Efficiency of silver nanoparticles for increasing shelf-life of horticultural crops

The major problems of post-harvest in horticultural crops include early senescence particularly in cut flowers which cause microbial contamination, inhibition of water uptake due to vascular system blockage, excessive water loss and enhancement in ethylene production. Alimoradi et al. (2013) found that nanosilver treatment at post-harvest stage extends vase life by retaining chlorophyll content and by preventing wilting. 5 mg/L of nanosilver pulse treatment have been found to enhance the vase life of *Gerbera* by inhibiting microbial growth and thereby preventing xylem blockage (Liu et al., 2009). Silver nanoparticles also enhance fresh weight and water conduction capability in tuberous flowers (Beni et al., 2013). Hatima et al. (2013) observed that enhancement of vase life of red rose take place if combinational pulse treatment of 5% sucrose and 50 mg/L silver nanoparticles was given as it enhances water uptake capacity and prevents loss of fresh weight. Byczyńska (2017) reported that 10 mg/L of silver nanoparticles extends the postharvest shelf life of cut tulip flower.

Utilization of silver nanoparticles in packaged food

In recent years, the demand for ready to eat food products is increasing. But maintenance of quality and prevention of contamination in the packaged food is a challenging task. This has led to the need of methods which can enhance the durability of the packaged foods. The effectiveness of nanoparticles in maintenance of the quality of cooked and packaged food has led to an increase in the demand of nano material in food packaging industry. The silver nanoparticles especially enhance the shelf life of packaged food by lowering the risk of pathogen contamination (Carbone et al., 2016). Zandi et al. (2013) reported that nanosilver based polypropylene and polyethylene containers help to maintain the ascorbic acid content of canned strawberry, which otherwise reduces with storage time. Shah et al. (2015) observed that shelf life of silver nanoparticles coated mandarin enhances by 120 days if stored at 4° C.

CONCLUSION

Silver nanoparticles are one of the easiest form of nanoparticles to be synthesized especially using the green method. The green method of nanoparticle synthesis, which utilizes plant extracts to reduce silver ion to nano silver, is a clean, environment-friendly and easy method of nanoparticle production. Further the green synthesized nanoparticles shows great potential as antimicrobial agent and have application in extension of self life of horticultural crop and in preservation of processed food.

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