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REVIEW ARTICLE

PARTHENIUM HYSTEROPHORUS: A NOXIOUS WEED

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ABSTRACT

Parthenium hysterophorus (Asteraceae family) is regarded as one of the worst weeds because of its invasiveness, fast growing habit and economic and environmental impacts. The vigorous mode of reproduction and the ability to possess of an arsenal of secondary metabolites has given it the status of invasive alien species. This noxious weed possesses large and persistent soil seed bank, high seed germination rate and ability to undergo dormancy under unfavorable periods. It is able to invade all disturbed land including farms, pastures and vacant lots and grows profusely along roadsides and railway tracks. This weed thus colonizes a range of vegetation and soil types and spread easily by water, farm and industrial machinery, animals, vehicles, stock fodder, movement of stock, grains and seeds. It affects each and every part of the ecosystem. It is considered to be a cause of a spectrum of clinical patterns: allergic respiratory problems, contact dermatitis, mutagenicity in human and livestock. During dry season, the mature plant crumble to a fine dust, that is scattered by the wind and becomes the source of "airborne contact dermatitis". Pollen grain of this weed produces hypersensitive disorders in susceptible individuals; the symptoms being watery eyes, swelling and itching of mouth and nose, constant coughing especially at night, continually running nose and sneezing. The plant produces toxic allelochemicals that affects the seed germination and the growth of the plants in its surroundings. Moreover, these substances are potent mitodepressive agents leading to several types of chromosomal abnormalities in dividing cells of plants growing in vicinity of this weed. Hence, it is also a threat to biodiversity of an area. The wide adaptability of the plant, its photo- and thermo-insensitivity and drought tolerance capacity in addition to allelopathic potential makes it a strong competitor in all habitats. There is also a growing concern that this weed will become more competitive and aggressive as concentration of carbon dioxide in the atmosphere increases i.e. due to green house effect. Looking at the harmful effect of the weed, there is an urgent need to control the population of this weed. However, it is a big challenge because of its high regeneration capacity, production of huge amount of seeds, high seed germinability and extreme adaptability to a wide range of ecosystems.

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INTRODUCTION

Parthenium hysterophorus is an aggressive, ubiquitous, annual, herbaceous weed belonging to Asteraceae family. The weed is known by different names like congress grass, carrot grass, star weed, white top, chatak chandani, bitter weed, ramphool and gajarghas in different parts of the world. It originated in tropical America, but also grows profusely in Australia, India, China and Kenya (Haseler, 1976; Navie *et al*., 1996). As it is injurious to human health, it is listed as a noxious weed by the governments of Australia, Kenya and Puerto Rico. Its high rate of seed production and their potential to remain dormant in soil as seed banks for long periods help the plant in its rapid introduction world-wide cutting across national boundaries and climate barriers. This weed is believed to have been introduced into India as contaminants in PL 480 wheat (Public Law 480 passed in 1954 to give food grains to developing countries for eliminating starvation and malnutrition) imported from the USA in the 1950s. Since then it has spread throughout the country and occupied all ecological niches. Presently, it is widely prevalent in India and is possibly the worst weed in both rural and urban areas (Kohli *et al.,* 2006; Singh *et al.,* 2008). It is estimated that approximately two million hectares of land in India is infested with this herbaceous menace (Dwivedi *et al.,* 2009). Moreover, due to its ability to invade and adapt to new habitats, it has become a threat to indigenous flora. Furthermore, cattle's do not feed on this plant thus resulting in its fast spread in the introduced regions (Javaid and Anjum, 2005). It forms a dense cover on the ground and shows its dominance over other vegetation. Apart from its competitive ability, the invasiveness of the noxious weed *P. hysterophorus* L. is thought to be due to an ability to displace other species by means of allelopathy.

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The sesquiterpene lactone parthenin that is biosynthesized by this species is thought to play a role in its allelopathic interference with surrounding plants. This suggested that the release of parthenin during decomposition of leaf material has a potential to play a leading role for allelopathy in *P. hysterophorus*; however, its significance in a natural setting will rely on the amount of leaf material accumulated on soil surfaces and the concentration of parthenin in residues. Although, parthenin is released from various plant parts into the soil, little but leaf residues are believed to deliver large amounts of parthenin to soils during decomposition and contribute significantly to overall allelopathic effects. Allelopathic potential of the weed also makes conditions favourable for its growth by inhibiting the growth and yield of the native plants growing in its vicinity. Due to its aggressive nature, it has become increasingly troublesome and difficult to control not only in India but also around the world.

Parthenium hysterophorus produces an array of secondary metabolites which adds to its aggressive nature in almost all habitats. Parthenin, hymenin, coronopilin, dihydroisoparthenin, hysterin, hysterophorin and tetraneurin are the principal constituents of the sesquiterpene lactones along with phytotoxic compounds like hysterin and ambrosin. Some of the flavonoids present are quercelagetin 3,7-dimethylether, 6-hydroxyl kaempferol 3-0 arabinoglucoside. The weed also produces phenol derivatives like caffeic, vanllic, ferfulic, chlorogenic and anisic acids along with some unidentified compounds. Parthenin, hymenin and ambrosin are reported to be responsible for the menacing role of this weed in provoking health hazards (Lata *et al.,* 2008). In humans, they are the causative agents of allergic ailments like bronchitis, dermatitis and hay fever. Parthenin has been reported from almost all the plant parts including trichomes and pollen (Reinhardt *et al.,* 2004; Sharma and Sethuraman, 2007). It also causes dermatitis in cattle and domestic animals. Though it is known for its harmful effects, but some useful properties such as insecticidal, nematicidal and herbicidal and its antimicrobial potential is also documented in literature (Oudhia and Tripathi, 1998a; Oudhia *et al.,* 1997a and b).

HABIT AND HABITAT

Parthenium hysterophorus grows luxuriantly in wastelands, vacant lots, forestlands, agricultural fields, urban areas and along roadsides and railway tracks (Fig. 1). It colonises weak pastures having sparse ground cover either due to overgrazing or unfavourable climatic conditions like drought. The weed tolerates a wide variety of soil but presents in alkaline and clay loam soils. It grows abundantly in areas having annual rainfall greater than 500 mm. It grows profusely not only in plains but even to an elevation of 2200 m above sea level and poses a potential risk to most grazing and cropping areas.

It is an erect annual herb up to 2 m in height with a deep tap root and an erect stem that becomes woody with age. Leaves are pale green in color, lobed, hairy, alternate, sessile, irregularly dissected and bipinnate. The number of leaves per plant varies from 6 to 55. The flowering starts about a month after germination with creamy white flower heads on the tips of numerous stems. Each flower contains four to five wedge-shaped black seeds, two millimeters long with two thin white scales. The plant is a prolific seed producer with single plant producing on an average 2,400–30,000 seeds during its life cycle (Haseler, 1976; Rodriguez and Cepero, 1984; Williams and Groves, 1980). The dispersal of its seed is via different means viz water currents, movement of vehicles, machinery, livestock, grain, stock feed and wind (Fig.2) (Sankaran, 2008). Seeds are capable of germination over a broad range of humidity, pH and temperature but high soil moisture is suitable for seed germination (Ahlawat *et al.,* 1979; Tamado *et al.,* 2002; Singh *et al.,* 2004).

Impacts

Parthenium weed has serious impact on each and every component of the ecosystem. Some of these are discussed below:

Fig. 1: *Parthenium hysterophorus* grown at different places: A) agriculture fields, B) & C) vacant lots, D) road side

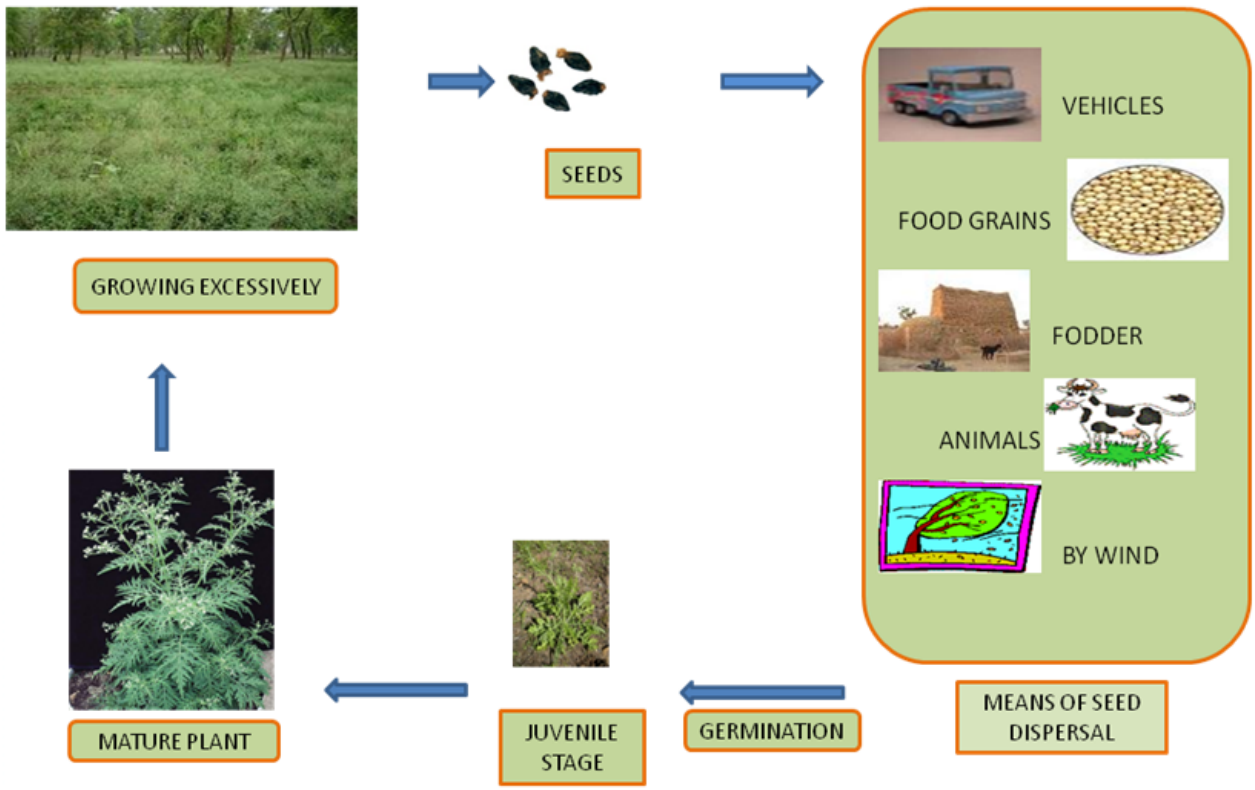

Fig.2. *Parthenium hysterophorus* life cycle

Human beings

The weed causes general infirmity, asthmatic problem, irritations of skin and stomach pains in humans (Wiesner *et al.,* 2008). Prolonged exposure to this weed evident the symptoms of allergic rhinitis, eczema, hay fever, burning and blisters around eyes and black spots. It is also a causative agent of allergic bronchitis, diarrhoea, severe papular erythematous eruptions, breathlessness and choking (Towers and Subba Rao, 1992; Maishi *et al.,* 1998). It is estimated that an exposure of 1-10 years to the weed, may develop sensitivity towards its dust and debris from the plant as well as pollen in 10-20% of the population (McFadyen, 1995). Nearly 10% of workers employed in infested areas in Queensland (Australia) possess noticeable allergic symptoms to this weed (Chippendale and Panetta, 1994). Allergic problems to pollen of *P. hysterophorus* have also been reported from different parts of India with thousands of cases of allergic contact dermatitis reported from Pune and Bangalore (Lonker *et al.,* 1974; Rao *et al.,* 1985; 1991). Studies carried out in Northern India (Punjab, Delhi) showed that a significant proportion of bronchial asthma patients are sensitive to its pollen (Suresh *et al.,* 1994). The role of sesquiterpene lactones (Parthenin, the major allergen) present in stem, flower and pollen of the weed have been implicated in contact dermatitis using patch testing (Lonkar *et al.,* 1976; Sharma and Sethuraman, 2007).

Livestock

In Queensland, Australia, losses to the cattle industry due to this weed have been estimated to be 16.5 million A$ per year in term of cost associated with its control and loss of pasture (Chippendale and Panetta, 1994). *P. hysterophorus* is a common cause of systemic toxicity in livestock (Gunaseelan, 1987). Alopecia, dermatitis, loss of skin pigmentation and diarrhea are some common problems associated with animals feeding on this plant. Furthermore, milk and meat of cattle, buffalo and sheep feeding on the weed becomes unpalatable due to its irritating odour (Lakshmi and Srinivas, 2007). Degenerative changes in both liver and kidney and inhibition of liver dehydrogenases have been reported in buffalo and sheep (Rajkumar *et al.,* 1988).

Crops

Since it is an aggressive colonizer, it reduces pasture growth and depresses forage production. The growth of indigenous plants growing in the vicinity of this weed is inhibited due to its allelopathic effect. Parthenin-sesquiterpene lactone plays a pivotal role in its allelopathic potential and it enters the soil through the decomposing leaf litter. It has been reported as a germination and radical growth inhibitor in a variety of plants (Gunaseelan, 1998). Aqueous extract of leaves exhibits considerable inhibitory effect on seed germination and seedling growth of crops like *Oryza sativa*, *Triticum aestivum, Zea mays*, *Raphanus sativus* and *Brassica campestris* (Maharjan *et al.,* 2007; Devi and Dutta, 2012; Khan *et al.,* 2012). Root exudates of the weed also inhibit the growth of plants growing in the vicinity (Belz *et al.,* 2007). Due to its fast growing nature and allelopathic properties, it also causes reduction in the yield of several crops. Upto 40% loss in the yield of rice and other crops has been reported from India (Oudhia, 1998). The extracts prepared from both unburned and burned plant parts were observed to be toxic to the seedling length and dry weight

of radish and chickpea (Singh *et al.,* 2003). Extracts from pollen and other plant parts of *Parthenium* also inhibits seed germination and fruits development in crops like chili, tomato, brinjal, etc. (Jarvis *et al.,* 1985).

Parthenium hysterophorus also interferes with the activities of nitrogen fixing and nitrifying bacteria viz., *Rhizobium*, Actinomycetes, *Azotobactor* and *Azospirilum* thereby affecting nodulation in legumes (kumar, 2012). It acts as an alternate host for the insect mealy bug and scarab beetle, a pest of sunflower in central Queensland (Robertson and Kettle, 1994; Tamado *et al.,* 2002b). The bacterial pathogen *Xanthomonas compestris* pv. Phaseoli, could be transmitted from the weed to *Phaseolus vulgaris* with reciprocal infection at the pre flowering and pod-formation stages (Ovies and Larrinaga, 1988). It also act as a suitable host for tobacco streak virus, tomato leaf curl virus and aster yellows phytoplasmas (Lee *et al.,* 2003; Sharman *et al.,* 2009; Reddy *et al.,* 2010).

Biodiversity

Allelopathic potential, high resistance and resilience capacity make *Parthenium* weed suitable for colonizing new areas by outcompeting native species. It is a serious threat to local fauna and flora and can cause severe reductions in the biodiversity of an area (Javaid *et al.,* 2007; Nigatu *et al.*, 2010). Growth inhibitors like lactones and phenols released from the plant into the soil either through leaching or as exudates of roots and decay of residues suppress the growth and yield of native plants. In many parts of the world, the weed has caused massive threat to the local biodiversity. The native plants in Einasleigh uplands bioregion are facing a strong competition from this weed (Sattler and Williams, 1999). The extensive growth of this weed has led to total habitat change in native Australian grasslands, open woodlands and along river banks (Lakshmi and Srinivas, 2007). It has also invaded the protected area like national parks and has caused detrimental effects on the vegetation (Evans, 1997).

Useful aspects

Though *P. hysterophorus* is an obnoxious herb, but if exploited by proper means and technology, it can prove to be a valuable resource. *P. hysterophorus* decoction has been used in traditional medicine to treat fever, diarrhoea, urinary tract infections, neurologic disorders, dysentery and malaria and as emmenagogue (Surib-Fakim *et al.,* 1996). Ethnobotanically, some tribes used it as a remedy for inflammation, skin rashes, cold, eczema, herpes, rheumatic pain, heart trouble and gynecological ailments. It is used as folk remedy in the Caribbean and Central America (Navie *et al.,* 1996). It can be applied externally on the skin and decoction of the plant is often taken orally as a remedy for a wide variety of ailments (Dominguez and Sierra, 1970; Morton, 1981). Paste prepared from the leaves when applied externally showed wound healing activity (Kumar *et al.,* 2012). In West Indies, this weed is used as a remedy against ulcerated sores, certain skin disease, facial neuralgia, fever and anemia (Bhatt *et al.,* 2012). The odour produced by a handful of *Parthenium* flower heads keep bees away. It can also act as a flea-repellent for dogs and other animals (Maishi *et al.,* 1998). Dry leaves powder of *P. hysterophorus* causes wilting and desiccation of above-water plant parts of *Salvinia molesta*, *Pistia stratiotes* and *Eichhornia crassipes* and thus can be effective in their eradication (Pandey, 1994).

Pharmacologically, *P. hysterophorus* has been found to be active analgesic in muscular rheumatism, therapeutic for neuralgia and as vermifuge (Maishi *et al.,* 1998). It is also a promising remedy against hepatic amoebiasis (Sharma and Bhutani, 1988). Root decoction of the plant is useful in treatment of dysentery (Singh *et al.,* 1996). Parthenin, the major constituent of the plant, exhibits significant medicinal attributes including anticancer property (Venkataiah *et al.,* 2003). Mew *et al.* (1982) demonstrated that sub lethal doses of parthenin exhibit antitumor activity in mice resulting in complete cure or increasing their survival time. Antioxidant potential of *Parthenium* has also been reported by several other workers. Extract of *P. hysterophorus* leaves prepared in different solvents like methanol, ethanol and acetone showed antioxidant activity by DPPH (2, 2-diphenyl-1-picrylhydrazyl radical) assay (Priya *et al.,* 2011). The extract of fresh leaves prepared in ethanol showed significant antioxidant activity in rats (200 mg/kg of body weight) (Pandey *et al.,* 2012).

The role of *Parthenium* as green manure, agent for bioremediation of toxic metals and dyes, herbicide, cheap substrate for enzyme production and source of biogas have been implicated in last few years. Bioremediation of heavy metals like nickel and cadmium is also reported by some workers (Ajmal *et al.,* 2006; Lata *et al.,* 2008). It can also be used for the production of enzymes like xylanases and as it is easily and abundantly present, the cost of enzyme production can be reduced (Dwivedi *et al.,* 2009). Silver nanoparticles have been synthesized by reducing silver ions present in the aqueous solution of silver nitrate complex using the extract of P. hysterophorus and can be converted into a valuable weed for nanotechnology-based industries in future (Parashar *et al.*, 2009). Applications of such eco-friendly nanoparticles in bactericidal, wound healing and other medical and electronic applications makes this method potentially exciting for the large-scale synthesis of other nanomaterials.

Management practices

As P. hysterophorus grows luxuriantly throughout the world and causes multitude of harm, its management is therefore necessary to control present and prevent future problems. The best strategy in the management is its excessive utilization as it is well documented for beneficial properties like insecticidal, nematicidal and herbicidal activities. It may also be used for mulching, for producing biogas, paper and compost. Above all, it use as a green manure should be promoted. Other practices that can be undertaken for its control are given below:

Physical management:

Small infestations of the weed can be eradicated by early detection and careful monitoring. However, an ongoing commitment is required to remove any seedlings that appear so that no new infestations are able to establish. Hand weeding therefore is the common and cheapest method in which plants

are uprooted before flowering or seed set by farmers manually mostly when the soil is wet (Goodall *et al.,* 2010; Tadesse *et al.,* 2010). However, it is not very effective as repeated removals are required over an extended period of time and it is very labor intensive task (Ganavel, 2013). Fire can also be used to control the spread of *Parthenium* but it is also not very effective as it destroys only those seeds which are close to the soil surface. Seeds covered under the soil remain unaffected by fire (Vogler *et al.,* 2002). However, burning of *P. hysterophorus* residues cannot be a recommended practice as it deteriorates soil quality by rendering it more alkaline and deficient in organic matter (Singh *et al.,* 2003). Moreover, smoke has been found to stimulate seed germination of the weed and seedling emergence in some cases (Adkins *et al.,* 2000; 2003). In addition to these, the use of inorganic mulches, like woven polypropylene groundcovers, can be effective in nurseries, especially if they are kept free of organic debris.

Chemical mangement

Chemical treatment of plants *via* herbicides is very useful and is recommended at an appropriate time *i.e.* before flowering and seed set in the plant. Glyphosate, atrazine, and metribuzin have been reported to be promising in controlling this weed. However they should be applied repeatedly as the seeds remain viable for 2–6 years (Butler, 1984; Navie *et al.,* 1998a; Tamado *et al.,* 2002). The herbicide barriers need to be in place during all times of the year when the seeds are likely to germinate. The cheapest method of control is spray of common salt solution (at 15- 20% concentration) in open wasteland, along railway tracks and roadsides and vacant lots.

Biological management

Biological control may prove to be the most cost-effective method for management of *Parthenium* and a combination of biocontrol agents will be helpful to suppress the spread of the weed (Dhileepan, 2007). Some of the insects have been studied for their ability to control the spread of this weed: Stem galling moth *Epiblema strenuana,* Bucculatrix parthenica (leaf-mining moth), Smicronyx lutulentus (seed-feeding weevil), stem-boring weevil *Listronotus setosipennis* and Zyogramma bicolorata Pallister (leaf-feeding beetle) have been reported to be effective against *P. hysterophorus* (Dhileepan, 2003a; b; Dhileepan 2007; McFadyen 1992; Navie *et al.,* 1998b, Dhiman and Bhargava 2010; Pandey *et al.,* 2001). Fungi like *Puccinia abrupt* var. *partheniicola* (*Parthenium* rust) and *Alternaria alternata* can also be used for biological control of this weed (Dhileepan, 2007; Saxena and Kumar, 2010).

Healthy and vigorously growing crops and/or native vegetation can contribute significantly to reduce the establishment and growth of *Parthenium* weed. Studies have shown that grasses and legumes can suppress its spread through competitive displacement/interference. *Imperata cylindrica* (L). Beauv. and *Desmostachya bipinnata* Stapf were found to reduce the distribution of *Parthenium* weed (Javaid *et al.,* 2005 and Anjum *et al.,* 2005). Seed germination and seedling growth of *Parthenium* has been shown to be inhibited by aqueous extracts of grasses viz., *Dicanthium annulatum* Stapf., *Cenchrus pennisetiformis* Hochest and *Sorghum halepense* Pers. (Javaid and Anjum, 2006). *Clitorea terneata* and *Digitaria milanjiana,* may also help to control the overgrowth of *Parthenium* (O,Donnell and Adkins, 2005). *Eucalyptus* oil may be used as natural herbicides for the biocontrol of *P. hysterophorus* (Kohli *et al.,* 1998). In field trials, *Tagetes erecta* and *Cassia sericea* has been reported to suppress the growth of *P. hysterophorus* (Lakshmi and Srinivas, 2007).

The management of *Parthenium* is difficult as it shows adaptability to a wide range of ecosystem. Moreover, its high regeneration capacity, high seed production and high rate of seed germinability also put restrains on its control. Mechanical, chemical and biological control strategies have proved to be futile individually in controlling the proliferation of *P. hysterophorus.* Hence, integrated approache is required to restrict the invasion of this weed in different geographical regions. To address this problem, there should be an increase in stakeholder's commitment to the eradication programme. Public awareness is to be an integral component of the management and participatory approach is required to control this aggressive weed. The community should be sensitized about the impact of *Parthenium* weed, and they should be skilled in its management. Studies on the utilization potential of this weed should also be encouraged and strategy of "control through utilization" should be adopted. Identifying the uses of the weed could pave way for indirect eradication of the weed. So, an integrated approach is required for the effective control of this weed.

Challenges

Major challenges are in management of this weed is : to raise awareness about the impact of *Parthenium* weed; the support and cooperation of stakeholders; to stop the spread of its seeds; improved integrated control and economically feasible management practices; and to coordinate nationwide management of *Parthenium* weed. Unless effective and efficient management is implemented and maintained, *Parthenium* weed will continue to impact adversely on agriculture, human health and the environment. Parashar *et al.* (2009) reported the synthesis of silver nanoparticles by reducing silver ions present in the aqueous solution of silver nitrate complex using the extract of P. hysterophorus. This discovery can promote this noxious plant into a valuable weed for nanotechnology-based industries in future. Applications of such eco-friendly nanoparticles in bactericidal, wound healing and other medical and electronic applications makes this method potentially exciting for the large-scale synthesis of other nanomaterials.

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