A REVIEW ON INDIAN TRIBAL PLANTS AND THEIR BIOGENIC PROPERTIES

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ABSTRACT

Green synthesis of silver nanoparticles (AgNPs) is considered to be nature-friendly and risk-free to the ecosystem. India is copious in biodiversity; the traditional medicine consists of the plant as a major component. The tribal people who lived in the rural region are entirely dependent on the tribal plants for their medical emergencies. These tribal plants have attracted the modern drug industry to develop drugs which are economical with minimal side-effects. The present study focuses on the tribal plants such as Aegle marmelos, Andrographis paniculata, Acacia arabica, Ficus religiosa, Cassia auriculata, Punica granatum, and Tinospora cordifolia used by the Bhilla, Irular, Dimasa, Paliyan Sholaga, and Dantewada tribes of India for their antimicrobial activity. Since these tribal plants are well known for its medicinal properties, the AgNPs synthesized from these plants were found to have enhanced antimicrobial activity than the pure plant extract.

Keywords: Green synthesis, Silver nanoparticles, Tribal plants, Antimicrobial.

INTRODUCTION

Ancient Greeks, Romans, and Egyptians considered silver has one of the potent agents and used it to preserve food and water due to its excellent antimicrobial properties. Hence, it was the third metal used by them next to gold and copper [1]. In addition, silver has been used in the traditional Ayurvedic medicine around 2000 years ago as silver ash, its colloidal and suspended form to restore the body. Even silver nitrate was used in medicine as wound healing, counterirritant, purgative, and also to treat brain infections [1,2]. Rajata, another name for silver during ancient Acharyas was used from the time of Charaka and is included in Charaka Samhita, a scheduled book of Ayurveda. Due to its clear, lustrous properties and due to its genuine properties such as bright whitening of metal during heating or cutting without any formation of furrows and ridges makes it valuable in therapeutics [3]. Rajata Bhasma was found to be effective in the enhancement of immune system due to its high solubility, absorbance, and catalyzing effect on the body [3,4], Nanotechnology is important in modern research due to its nano-sized particle ranging from 1 to 100 nm and its wide range of applications in medicine [5,6] as theranostic agents [7], in delivering ocular drugs to the target site in ophthalmology [8], as nanoparticle-assisted drug delivery to the skin as it can act as route for delivery of local and systematic drug as anti-inflammatory drugs, anti-phototoxic drugs, antioxidants, antimicrobial agents [9,10], targeted chemotherapeutic agent, and nanodots are used [11]. In food industry, nanoparticles are employed to detect contaminants or microbes present in packed foods and also to prevent obesity in the form of nanofoods [12]. Nano-enabled water and wastewater systems can increase the treatment efficiency of alternative water resources [13]. It is also used in the textile industry especially due to its high durability for fabrics, excellent protection from ultraviolet rays, anti-static property and has good resistance to wrinkles of cotton and silk [14]. In the agricultural field, nanomaterials can be used to improve the efficiency of seed germination, to protect the plants by detecting the pathogens and pesticide residue [15]. Also used in electronic storage systems [16].

Metallic nanoparticles, in the form of colloids or sols, are used for ornamental decorations by the middle ages [17] are of noble metal nanoparticles (NMNs) and non-NMNs. Noble metals include ruthenium (Ru), rhodium (Rh), palladium (Pd), silver (Ag), osmium (Os), iridium (Ir), platinum (Pt), and gold (Au) where these metals are inert and hence resistant to corrosion unlike non-noble metal [18]. Among these metals gold (Au), silver (Ag), and platinum (Pt) has unique and adjustable electrical, optical, structural parameters (size, shape, composition, surface) and chemical properties, high surface area, good stability, and good biocompatibility. Since NMNs consists of better selectivity and activity than transition metals, it can be used in many environmental applications [19,20]. Non-noble metals can be used along with noble metal to synthesize bimetallic nanoparticle which has high catalytic activity [21] and has the potential for adapting the electron distribution of alloy nanoparticles. Non-noble metals also have some less expensive metals such as Fe, Co, Ni, and Cu has been developed for the dehydrogenation of ammonia borane [22].

Silver as a noble metal has its origin from ancient time has rich esthetic and medicinal values, where it is known by different names such as Dutch (ziwer), German (Silber), and Anglo-Saxon (seolfor), Greek (Argyros), Latin (argentum), Italian (Argento), French (argent) and Spanish (Plata). In addition, silver is used in bone prostheses, ophthalmic surgery, veterinary medicine, desalination of seawater, and as active adsorbent [16]. It is believed that colloidal form of silver has the high germicidal activity such as antibacterial, antifungal, antiseptics, and no toxicity against humans [23]. Due to its antifungal property, silver nanoparticles (AgNPs) are extensively used to prevent biofouling on the surface of the cathode [24]. AgNPs has gained boundless interest due to their unique properties such as chemical stability [25,26], good conductivity [27,28], catalytic [29] and most important antibacterial [30,16] antifungal [31], antiviral, [32-34] and anti-inflammatory activities [35-37]. In addition, silver has occupied a major place in consumer products where some of the products are toothpaste, as an engineered nanomaterial get exposed to environment and makes available for humans through drinking water, humidifiers, and through soil [38,39]. It is used in clothing to protect from body odor, medicine such as acne creams and sulfadiazine creams, cosmetics, baby pacifiers, washing machine, and electronic gadgets [40]. The AgNPs used in industry for developing commercial products found to contain AgNP in their wastewater and it was found that its presence does not affect the chemical oxygen demand removal [41].
Table 1: Synthesis of AgNPs using different parts of tribal plants

<table>
<thead>
<tr>
<th>S. No</th>
<th>Tribal plant name</th>
<th>Part used</th>
<th>Characterization</th>
<th>Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>A. marmelos</em></td>
<td>Leaf</td>
<td>UV-420 nm; XRD-fcc; FTIR</td>
<td>Antimicrobial action against <em>B. subtilis</em> and <em>P. aeruginosa</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fruit</td>
<td>UV-421 nm; XRD-24 nm (fcc), TEM-18–30 nm; HRTEM-24 nm</td>
<td>Antibacterial activity against <em>E. coli</em>, <em>B. cereus</em>, <em>S. aureus</em>, <em>P. aeruginosa</em> was carried on and the maximum antibacterial activity was observed against <em>B. cereus</em></td>
</tr>
<tr>
<td>2</td>
<td><em>A. paniculata</em></td>
<td>Leaf</td>
<td>UV-410 nm; XRD-fcc; SEM-35–55 nm, spherical; EDX</td>
<td>Antiplasmodium activity against <em>P. falciparum</em> revealed lowest inhibition rate at IC50, 2.5 µg/ml (20%) and highest inhibition at 100 µg/ml (83%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Whole plant</td>
<td>UV-430 nm; SEM-40–80 nm, spherical; TEM-14–26 nm; FTIR</td>
<td>Antibacterial activity against <em>S. aureus</em>, <em>P. aeruginosa</em> and <em>E. coli</em>. Antifungal activity against <em>A. niger</em> and not on <em>A. flavus</em></td>
</tr>
<tr>
<td>3</td>
<td><em>A. arabica</em></td>
<td>Gum</td>
<td>UV-462 nm; SEM-spherical, 35 nm; XRD-crystalline; SAED-94%; ICP-AES</td>
<td>AgNPs synthesized were effective against both <em>B. subtilis</em> and <em>P. aeruginosa</em>. Where, AgNPs is more potent against Gram-positive than Gram-negative bacteria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bark</td>
<td>UV-430 nm; TEM-40–55 nm; XRD-Fcc, 45 nm; SEM-Spherical, 40–50 nm; FTR, EDX; FTIR</td>
<td>Antimicrobial activity against <em>S. aureus</em> and <em>P. aeruginosa</em>, which showed potential antibacterial activity against <em>S. aureus</em></td>
</tr>
<tr>
<td>4</td>
<td><em>F. religiosa</em></td>
<td>Leaf</td>
<td>UV-430 nm; SEM-spherical, 5–50 nm; XRD-fcc, 4 nm; AFM-W=280 nm, T=4 nm</td>
<td>FESEM and AFM confirms the particles are polydispersed. The reduction of silver ions and stabilization of the AgNPs was due to the participation of quinones and flavonoids</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Latex</td>
<td>UV-422 nm</td>
<td>AgNP were collected from latex of 6 different plant where among them <em>F. religiosa</em> ranks 3rd depending on the size of AgNP</td>
</tr>
<tr>
<td>5</td>
<td><em>C. auriculata</em></td>
<td>Leaf</td>
<td>UV-450nm; XRD-Rcc, 20.84 nm; SEM-spherical, 20–40 nm; FTIR</td>
<td>The synthesized AgNPs are stable where the control of shape and size of AgNP is easy due to selection of plant leaf extract</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flower</td>
<td>UV-436nm; TEM-circular distribution, spherical, XRD-50–70 nm, Fcc; EDX; FTIR</td>
<td>The synthesized AgNP exhibited antibacterial activity against <em>S. typhi</em>, <em>K. pneumonia</em>, <em>E. faecalis</em> and <em>E. coli</em>, except <em>S. aureus</em></td>
</tr>
<tr>
<td>6</td>
<td><em>P. granatun</em></td>
<td>Seed</td>
<td>UV-472 nm; XRD-Fcc, 10–30 nm; SEM-nano flower and spherical, 10–30 nm; EDX; FTIR</td>
<td>AgNPs produced showed effective antibacterial activity against <em>B. cereus</em> with 14 mm zone of inhibition than <em>Pseudomonas, S. albus</em>, Proteus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fruit peel</td>
<td>UV-448 nm; XRD-Fcc, 15–35 nm; SEM-nanoflower and spherical, 10–30 nm; EDX; FTIR</td>
<td>AgNP produced is effective against <em>B. cereus</em> with 17 mm inhibition zone than <em>Pseudomonas, S. albus</em>, Proteus.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leaf</td>
<td>UV-400 nm</td>
<td>Antibacterial activity against <em>B. cereus</em>, <em>Pseudomonas, S. aureus</em> were studied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flower</td>
<td>UV-450 nm</td>
<td>Antibacterial activity against <em>B. cereus</em>, <em>Pseudomonas, S. aureus</em> were studied. Where <em>Staphylococcus</em> showed maximum inhibition zone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fruit</td>
<td>UV-490 nm</td>
<td>Antibacterial activity against <em>B. cereus</em>, <em>Pseudomonas, S. aureus</em> were studied</td>
</tr>
</tbody>
</table>

(contd...)
Tribal plant UV- 420–425 nm; TEM- UV- 556 nm; FTIR; PCA Characterization

Antimicrobial activity was exhibited against E. coli,
P. aeruginosa and P. vulgaris, zones of inhibitions 8–16 mm

Antimicrobial activity was exhibited against E. coli,
P. aeruginosa and P. vulgaris, zones of inhibitions 9–16 mm

The AgNPs produced from the plant showed high antibacterial activity against both Gram-positive and Gram-negative bacteria than the pure plant extract. The AgNPs produced showed high activity against Staphylococcus sp. and Klebsiella sp. than Bacillus sp. T. cordifolia acts as very good multi drug resistant agent against P. aeruginosa

SYNTHESIS OF AGNPS

AgNPs can be synthesized by several methods. Among the huge number of methods available in physical method evaporation-condensation and laser ablation approaches are commonly used to produce large quantities of AgNPs. However, this method is not widely used due to its time-consuming procedure, expensive equipment, and high operating conditions [5]. In the case of chemical synthesis of AgNPs, many methods are available such as chemical reduction method, polyol method, radiolytic method and much more. In comparison with the physical method, by chemical method AgNPs can be produced at low cost, simple equipment and in high yield. The three major components involved in the chemical synthesis process are the metal precursor, reducing agents (organic and inorganic), stabilizing, or capping agents [42,43]. These components used are of toxic and hazardous chemicals and they contain potential environmental risks [42].

Whereas the green synthesis method is a quick process, economic, safe to environment, and humans [44]. Some of the green synthesis methods involve polysaccharide method, irradiation method, biological method, polyoxometalates method, and tollens method. The biological method is mostly used where one its sources consist of plants, algae, diatoms, bacteria, yeast, fungi, and human cells [44,45]. Plant-mediated synthesis is an attractive method for nanoparticle synthesis and considered as the best option among other biological methods due to its effective inhibitory action against extensive drug resistance microbes [46]. In addition, nanoparticles can be synthesized at ambient temperature, low cost, short production time, and in large volume [44]. Here, due to the presence of phytochemicals, the silver nitrate will be reduced to AgNPs where the biomolecules present in it act as both reducing and capping agent, making the process easy and reliable [47,48].

TRIBAL PLANTS

There are various tribal communities worldwide who lives as scattered and small groups in the plains, forest, hills, and distant areas from the mainstream population. Their social, cultural, and economic patterns differ from one region to another. The largest tribal population was found in India which comprises 8.6% of the total population of the country. India consists of 29 states and 7 union territories where the tribal population of India belongs to three races, namely, the proto- australoids, the mongoloids, and the negritos. In addition, the Indian tribes have been denoted by different names such as Vanayaji (caste of the forest), Vanavasi (inhabitants of forest), Pahari (hill dwellers), Adimjati (primitive people), Girijan (hill dwellers). Anusuchit Jan Jati (scheduled tribe) [49-51].

These indigenous people maintain a close relationship between the man and the surroundings and hence found to have great knowledge on the use of plants to cure various diseases, where nearly 6500 plants were used by the traditional healers in Southeast Asia. The documentation of the tribal plants and its traditional uses as medicine has conquered the modern drug industry, where the inborn antimicrobial activity of the tribal plant can be enhanced by its respective synthesis of AgNPs [52-54]. These tribal plants can also act as a potent source to develop anticancerous and antibiological drugs with low or no side effects for the user [55].

Aegle marmelos

1. Kingdom: Plantae
2. Family: Rutaceae
3. Genus: Aegle
4. Species: A. marmelos.

A. marmelos is a subtropical species which can adopt a wide range of habitat and hence can be cultivated worldwide. It is native to India and the tree grows wild in dry forest of central and southern India, Burma, Pakistan and Bangladesh, it is also grown in Nepal, Myanmar, Tibet, Ceylon, Vietnam, Laos, Cambodia, Sri Lanka, Thailand, Indonesia, Malaysia, Surinam, and Northern Luzon of Philippine Islands. A. marmelos is a slow-growing, medium-sized tree which can grow up to 12–15 m tall. It has a short trunk, and its bark is thick, soft, flaking, and spreading. The wood of this tree is used as carts and for construction purposes. From the wounded branches, the gum is discharged slowly which tastes sweet first and irritating to the throat later. This gum is used as adhesives. The leaves are deciduous, arranged in an alternate fashion where 4–10 cm long and 2–5 cm wide oval, pointed, shallow-toothed leaflets are present. These leaves cause sterility in women and its extract consists of insecticidal activity against brown planthopper. The tree produces fragrant flowers in the month of April and May with green outside and yellow inside along the young branches. The fruits produced were found to be edible and have different shapes such as oval, flat, spherical, oblong, and pear grows up to 5–20 cm in diameter. The fruit has thin hardly shell grey-green outside where it takes 10–11 months to ripen and appears yellowish in color [56,57].

Table 1 (continued)

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<tbody>
<tr>
<td>7.</td>
<td><em>T. cordifolia</em></td>
<td>Leaf</td>
<td>UV- 430 nm; XRD- 24 nm, fcc; SEM- spherical; EDX; FTIR</td>
<td>The AgNPs produced from the plant showed high antibacterial activity against both Gram-positive and Gram-negative bacteria than the pure plant extract. The AgNPs produced showed high activity against Staphylococcus sp. and Klebsiella sp. than Bacillus sp. T. cordifolia acts as very good multi drug resistant agent against P. aeruginosa</td>
</tr>
<tr>
<td></td>
<td><em>Tinospora cordifolia</em></td>
<td>Stem</td>
<td>UV- 420–425 nm; TEM- spherical, 36x9 nm; XRD- 12.49 nm; FTIR</td>
<td></td>
</tr>
</tbody>
</table>

**UV-Vis:** Ultraviolet-visible, **FTIR:** Fourier transforms infrared, **EDX:** Energy dispersive X-ray, **SEM:** Scanning electron microscopy, **TEM:** Transmission electron microscopy, **XRD:** X-ray diffractometer, **fcc:** Face-centered cubic, **CV:** Cyclic voltammetry, **HRTEM:** High-resolution transmission electron microscopy, **SEAD:** Selective area electron diffraction.
The Bael tree is considered as one of the most sacred trees of India [58]. The B. marmelos is used by the Bhil tribe of Maharashtrat to treat snake bite. The snake-bitten part is treated by applying the leaf juice and in case of nausea, squeezed leaves are swallowed [59]. The chemical constituents present in the different parts of this tree are alkaloids, coumarins and steroid [58]. Due to the presence of various phytochemical constituents, it is used in Ayurveda and in ethnomedicine since it has potent antibacterial, antifungal, antiviral, antioxidant, anticancer, antitumor, antiviral, anti-inflammatory, anti-infective, and antihypertensive activities [58,60,61].

**Andrographis paniculata**
1. Kingdom: Plantae
2. Family: Acanthaceae
3. Genus: Andrographis
4. Species: A. paniculata

*A. paniculata* is also known as the king of Bitters is an annual herb cultivated in tropical and sub-tropical Asia, Southeast Asia, India, China, America, West Indies, Bangladesh, Hong Kong, Pakistan, Philippines, Malaysia, Indonesia, and Thailand. *A. paniculata* is an herbaceous plant which grows in moist shady places to a height of 30–110 cm. The stem of this plant is tetragonal in shape with glandular hairs outside. The leaves are green or copper shade arranged in a simple, opposite decussate fashion of 6–10 cm long and width 3.5–5 cm. The flowers are the complete one, bisexual in nature, hypogynous, pentamerous, and appear pinkish violet in color. Fruits are dry dehiscent, flat capsules with length 12–17 mm and width 2–3.5 mm, on maturity it appears as dull brown in color. The three layers in the root are packed together with visible secondary growth. The root and leaf are the major parts used in the traditional medicine to treat skin infections, respiratory diseases, herpes, dysentery, fever, sore throat, lower urinary tract infections, and diabetes and to reduce inflammation. The bitter and cold property of this herb is considered in the traditional Chinese medicine, and hence, it serves as a remedy for acute infections such as tonsillitis, gastroenteritis, gynecopathies, and pneumonia [65]. The phytochemicals found in the *A. paniculata* are a lot of terpenoids such as diterpenoid lactones and various other compounds like flavonoids such as flavones; xanthones; noriridoids; and polyphenols. The plant is known for its antimicrobial, anti-inflammatory, anti-allergic, immunostimulant, anti diabetic, anticancer, anti-oxidant, and anti-protozoan activities. It also possesses the ovicidal and larvicidal activity against *Culex quinquefasciatus* and *Aedes aegypti*; anti-inflammatory activity, anti-angiogenic activity, and hepatoprotective activity [65,66].

**Acaea arabica**
1. Kingdom: Plantae
2. Family: Mimosaefae
3. Genus: Acaea
4. Species: A. arabica

*A. arabica* is a multipurpose tree, found widely distributed in tropical and subtropical regions of India, Sri Lanka, Australia, Africa, and Egypt. *A. arabica* is a perennial tree which usually grows up to 2.5–10 m tall. Thinn, dark reddish-brown bark is present with purple-brown branches where the leaves grow up to 30–40 mm long. Golden yellow flowers are present with straight pod, and the seeds are found to be round in shape. The yellow color gum is secreted from the cuts of the bark where this has various medicinal properties [67] and hence used to treat diarrhea and dysentery when mixed along with quinine, also can be applied to the burns. Almost all parts of *A. arabica* are used for medicinal purposes where the leaves are used to treat ulcers; bark is used to treat gonorrhea, leukorrhea, as a mouthwash, for eye conjunctivitis; roots are used to reduce burning sensation of the skin [68]. The tribal tribes which reside in Redhills, Tamil naidu, uses the bark of *A. arabica* as a remedy for tooth problems [69]. The phytochemical studies of *A. arabica* prove the presence of tannins, terpenoids, alkaloids, glycosides, and saponins [68,70]. Studies reveal that *A. arabica* is involved in various activities such as antioxidant, antihyperlipidemic, antioxidant [71], antitumor, antiviral, anti-inflammatory, anti-diabetic, and antihypertensive, and as antispasmodic [72].

**Ficus religiosa**
1. Kingdom: Plantae
2. Family: Moraceae
3. Genus: Ficus
4. Species: F. religiosa

F. religiosa also was known as the Bodhi tree is considered as the sacred tree and found in India, Nepal, Thailand, Pakistan, and Israel. F. religiosa is a 20 m tall deciduous tree with grayish bark and alternate arrangement of green leaves. Sesile axillary flowers are found in the month of February. The green colored fruits are in round shape which turns to purple color with red dots once matured [57,73]. In ethnomedicine, its leaf extract along with honey is used to treat asthma, cough, diarrhea, migraine, eye troubles, toothache, and sexual disorders. The fruit paste is applied on the burns to heal the wounds. The stem bark acts as anti-septic, anti-dote, and astrigent, and its aerial root juice finds a remedy to menstrual problems [74]. This plant has great ethnomedical value and is used by the Dimasa tribe of Assam where its root extract is used in the treatment of jaundice [75]. Phenols, tannins, steroids, alkaloids and flavonoids, Vitamin K, n-ocasosanol, methyl oleanolate, lanosterol, stigmasterol, lupen-3-one, β-sitosteryl-D-glucoside, phytosterol, albuminoids, caoutchoue, kaempeferol, quercetin, myricetin, phytosterols, bergapenteg, and linalolic acid are the phytochemical constituents of this plant [76]. The presence of various chemical constituents makes the plant to be involved in anti-diabetic, antimicrobial, antiviral, anti-inflammatory, anti-asthmatic, anti-convulsant, parasympathetic modulatory, estrogenic, antitumor, antitumor, and antihypertensive activities [76-78].

**Cassia auriculata**
1. Kingdom: Plantae
2. Family: Caesalpiniaceae
3. Genus: Cassia
4. Species: C. auriculata

*C. auriculata* is a sacred tree and found in India, Nepal, Thailand, Pakistan, and Israel. It is considered to be a sacred tree in India and Sri Lanka, and it is prominently found in South India throughout the year. The stem of this plant is tetrangular in shape with glandular hairs outside. The leaf and flowers act as a potent antimicrobial agent [84]. Other constituents, it is used in Ayurveda and in ethnomedicine since it has potent antibacterial, antifungal, antiviral, antioxidant, anticancer, anti-inflammatory, antiperoxidative, antidiabetic and antihyperglycemic are possessed by the plant. The whole plant powder along with cow's milk, used to treat diarrhea when taken internally. The plant is also known for its antimicrobial activity where the leaf and flowers act as a potent antimicrobial agent [84]. Other activities such as antioxidant [85], antipyretic, hepatoprotective, antitumor, antitumor, and antihyperglycemic are possessed by this plant [86].

**Punica granatum**
1. Kingdom: Plantae
2. Family: Lythracea
Various difficulties in the pharmacological industries. Hence, this tribal
plants used by different tribal communities and
studies. In addition, the biogenic properties of
ability of these tribal plants to produce its respective AgNPs with a
study, different tribal plants used by different tribal communities and
searches about the novel tribal plants in
and around the area for antimicrobial activities. It promotes a better
understanding of the native plants and their inborn therapeutic
values. The author has contributed in language correction and in
formulating reference session.

Anjali Lakshmi D is a Research scholar at Department of Chemical
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includes Chemical engineering applications in wastewater treatment,
solid waste management, Leachate treatment and Management.

CONFLICT OF INTEREST
None declared.

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Authors contribution
1. Anjali K: The main author of the work is currently doing project on
tribal plants and their inborn microbial activities and came up with
the structure and model of the manuscript.
2. Anitha Jegadeeshwari L: researches about the novel tribal plants in
and around the area for antimicrobial activities. It promotes a better
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Formatting of table, font reference has been done by this scholar.

Nagendra Gandhi N: Corresponding Author is the project mentor.
He is the Professor and Head of Chemical engineering department,
ACT Cam pus, Anna University, Chennai. His areas of interest include
Extraction, Green Technology, Hydrotherapy, Environmental studies,
Mass transfer, separation technologies. He has more than 70 journals
published and has presented at many national and international
conferences. He has conducted many workshops.

Conflict of Interest
None declared.
Crop Protect 2012;35:64-70.


