Chapter

# Increasing Trend of Silver Nanoparticles as Antibacterial and Anticancer Agent

*Attique Ur Rehman Khan, Muhammad Adnan, Shaheen Begum, Ruqia Nazir and Sakina Mussarat*

## Abstract

Silver nanoparticles (AgNPs) synthesis from plants that already have been reported for medicinal purposes demonstrated better efficacy for curing diseases. Recently, a number of researches have been reported where AgNPs act as promising antibacterial and anticancer agent. Biosynthesized silver nanoparticles (AgNPs) are a type of environmentally friendly, cost-effective, and biocompatible substance that has gotten a lot of attention in treatment of cancer and inhibition of pathogenic microbes. In this chapter, a comprehensive report on the recent development of AgNPs as nanomedicine synthesized from plant extracts. The role and mechanism of AgNPs as antibacterial and anticancer agent was reported that leads towards development of targeted nannomedicines to treat infectious diseases and world most challenging disease like cancer. Reported literature give imminence importance of AgNPs and demonstrated more potency to treat cancer and bacterial infections.

**Keywords:** silver nanoparticles, biolabeling, conjugation, phagocytosis, polydispersity

## 1. Introduction

Silver has been used widely from ancient times as it is a noble metal. Hippocrates advocated for the use of silver in the treatment of sickness and for healing purposes [1]. Silver is found abundantly in nature with multiple biological and biochemical properties making silver most suitable candidate for the biomedical applications, can be used as an antiseptic, part of medicines, antimicrobial efficacy, pharmaceutical industry, Food preservation, cosmetics, biolabelling, and optical properties. AgCl and AgNO3, ionic forms of silver, caused cardiac alterations in rats, such as left ventricular hypertrophy, hypersensitivity, and inhibition of normal fibroblast function [2]. Silver nanoparticles (AgNPs) are comparatively safe and more effective in medical treatment to silver ions [3].

Recently, nanotechnology has played a critical role in biomedical, diagnosis, treatments, the industrial sector, scientific purpose, and environmental protection [4]. Nanomaterials have a size range of 1–100 nm, or particles with at least one dimension

smaller than 100 nm [4]. Due to unique physicochemical and biological characteristics, such as large surface area to volume ratio, excellent surface plasmon resonance, conjugation with various ligands to obtain desired property, inhibition against microbes, potent toxicity towards cancer cells, catalytic operations, silver nanoparticles are one of the most widely studied metal nanoparticles for a variety of scientific purposes. Due to very small size they penetrate the blood capillaries and tissues and become more effective in cancer treatment. Moreover they carry the multiple drugs on their large surface area and have capability to modify and combine chemically. Antimicrobial and anticancer activities of green synthesized AgNPs is due to phytoconstituents attached on their surface [5]. Several research studies have been conducted a green method to synthesize a range of metallic nanoparticles in concern with growing worldwide burden of cancer that showed potential anticancer effect against a range of cancer cell types [6]. Unicellular or multicellular living organisms are typically with 10 μm, so AgNPs in small size (1–100 nm) can interact with cell wall of bacterial, viral, and fungal pathogens and their active nano-complexes can penetrate and break the external capsule. The permeability of the plasma membrane to small-sized AgNPs permits them to accumulate in cell compartments. Phagocytosis, endocytosis, or micropinocytosis is the uptake mechanisms of nanoparticles in eukaryotic cells [7].

The rising applications of AgNPs in field of oncology and microbiology, present chapter emphasizes the significant antibacterial and anticancer properties of AgNPs synthesized by the green approach, recent developments and finding new perspectives in nanomedicine. In comparison with other methods, Ram Prasad's methods have been shown to be better due to their slow kinetics and ability to manipulate crystal growth and stabilization in a better way. The biogenetic synthesis uses plant extracts in aqueous form to create noble nanoparticles, as the extracts contain more reducing agents than plants. The availability of silver nanoparticles and their various metabolites makes plant-mediated silver nanoparticle synthesis a preferable method [8]. There are several phyto-constituents that are believed to reduce silver ions, including tannins, terpenoids, flavonoids, ketones, aldehydes, amides, and carboxylic acids. Plant extracts (chemical composition, amount, conjugation method) and nanoparticles (type, size, shape, polydispersity, etc.) play an influential role in the properties of a bioconjugate method [9].

In addition to being expensive to manufacture, the silver ion method has not been demonstrated to be clinically effective in randomized controlled trials and cannot be used with oxidizing solutions such as hypochlorite or $H_2O_2$ [10]. There are several drawbacks to the generation of silver nanoparticles (AgNPs) using a tube furnace, including the fact that it occupies a large space, consumes a lot of energy, raises the temperature in the surrounding environment, and requires a lot of time to achieve thermal stability. To achieve a stable operating temperature, a tube furnace typically requires several kilowatts and several time of preheating [11]. The polysaccride method is very temperature sensitive because the binding between the silver nano particles is very weak. If the temperature is increased slightly then the reversible reaction is started and the separation of the silver nano particles is started so the nano particles are unstable [12].

## 2. Applications and importance of silver nanoparticles

Nanoparticles and nano-composites synthesized from plants containing noble metals, silver nanoparticles are widely used metal due to incredible potential and significant usage. The diverse chemical and physical nature of AgNPs suggests

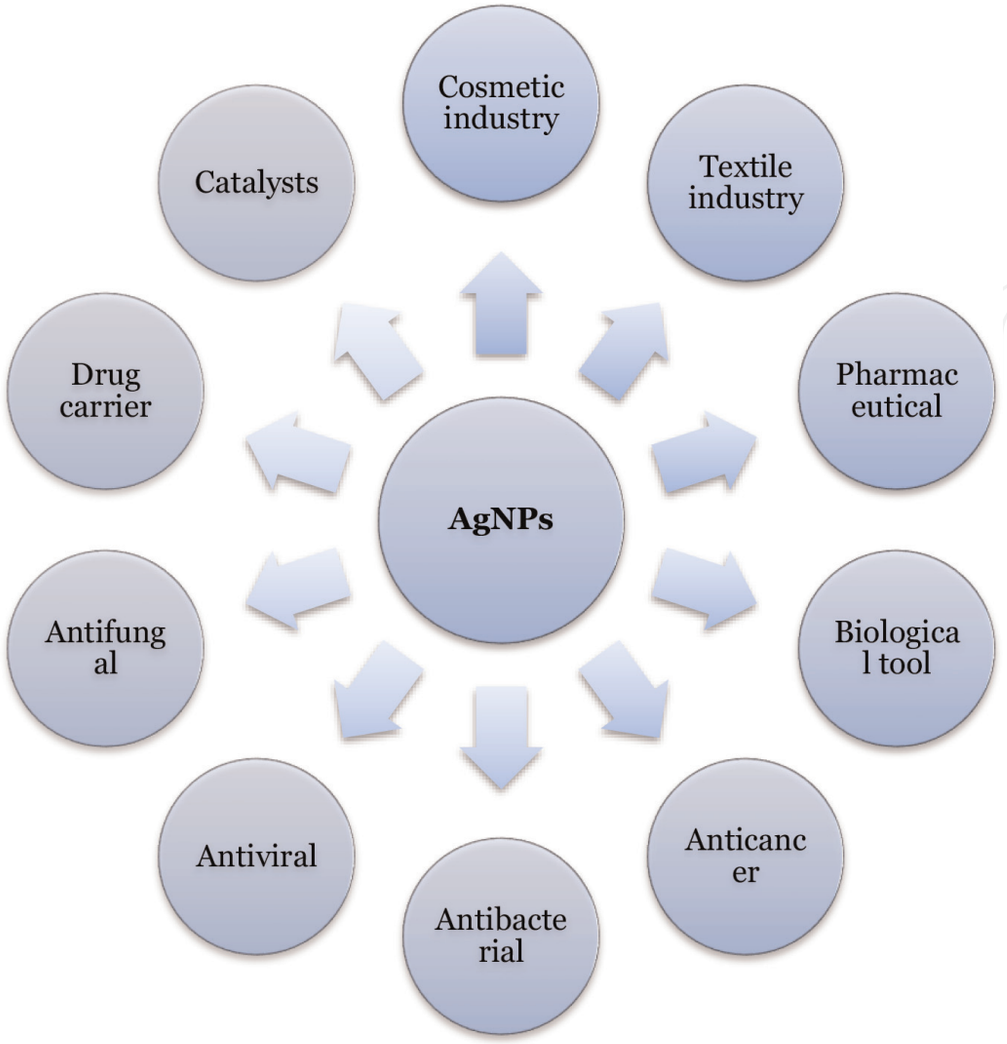


**Figure 1.**
*Applications of AgNPs.*

potential uses in the environment and for the well being of human life, promoting one health program for example cover the field of agriculture, food industry, medicine, and for the better human health (**Figure 1**) [13–15]. In the treatment of cancer cells, AgNPs are used as therapeutic agents due to cellular oxidative and apoptotic potential [15, 16]. AgNPs offer new uses due to their size-dependent actions and capacity to form various complexes with natural or synthetic molecules [17–19].

AgNPs are the most studied zero-dimensional nanoparticles for their remarkable and unparalleled uses in pharmaceutical science, infectious problems, wound care, antimicrobial, food packaging, and the cosmetic sector [20]. In recent years, biosynthesized AgNPs have shown potent larvicidal, bactericidal, fungicidal, antioxidant, antiviral, antidiabetic, and anticancer activities [21]. There are approximately 383 commercialized nano silver-based products on the market worldwide, accounting for 24% of all nano products [22].

### 2.1 Silver nanoparticles as anticancer agent

Cancer is one of the most challenging diseases to treat, and defined as the uncontrollable division of altered cells. It is the leading cause of mortality and about 70%

deaths in middle and low income countries and 68% population suffer due to cancer [23]. Globally cancer burden will be rise up to 27 million by 2040 [24]. Cancers most commonly diagnosed in the human population include lung, thyroid, cervical, liver, stomach, brain tumors, prostate, uterine, and breast cancers [19]. The most predominantly prevalent cancer are breast and prostate cancer that effect women and men, respectively. The field of cancer nanobiotechnology has provided new direction to detect, diagnose, and treat cancer [25]. AgNPs produced through green method with phytochemical covering give them more efficacy than AgNPs produced through chemical method. The ability to combine AgNPs inherent anticancer property with the pharmacological anticancer effects could be the key to treating malignancies that have stopped responding to chemotherapy or radiotherapy. Metal-based AgNPs have been found to be pro-oxidative in a variety of cancer cell types. The phytoconstituents berberine isolated from plants in combination with AgNPs showed synergistic anticancer activity [26]. Several studies in the published literature have looked into the methods by which AgNPs exhibit anticancer action. Among studied cancer cell lines most of the silver nanoparticles are studied against breast cancer cell line MCF-7. The size of AgNPs evaluated for anticancer ranged from 5 to 100 nm; with varying shapes such as spherical, cubical and hexagonal. The IC50 values of green synthesized AgNPs extracts against studied cell lines ranged from 6 to 1200 μg/mL. Some important studies regarding *in vitro* evaluation of AgNPs on cancerous cell lines represented in **Table 1**. AgNPs synthesized from *Mentha species* possess inhibitory effect against

| Plant used | Part used | Size (nm) and shape of AgNPs | Cancer cell line | $IC_{50}$ value (μg ml − 1) | Reference |
|---|---|---|---|---|---|
| *Avicennia marina* | Leaves | 10 (spherical) | A549 lung cancer cells | 15 | [27] |
| *Litchi chinensis* | Leaves | 59 (spherical) | MCF-7 | 40 | [28] |
| *Fagonia indica* | Whole plant | 10–60 (spherical) | MCF-7 | 12.3 | |
| *Ganoderma neo-japonicum* | Fruit | 5–8 (spherical) | MDA-MB-231 | 6 | [29] |
| *Putranjiva roxburgi* | leaves | 8 (spherical) | MDA-MB-231, HCT-116 and PANC-1 | 0.54–0.00025 | [30] |
| *Jasminum officinale* | Rhizome | 9.2 (spherical) | MCF-7, Bladder (5637) | 9.3–1,13.0 | [31] |
| *Noctiluca scintillans* | callus | 4.2 (spherical) | MDA-MB-231 | 50 | [32] |
| *Euprenolepisprocera* | Leaves | 60 (spherical) | MCF-7 | 9.63 | [19] |
| *Nostoclinckia* | Whole | 9.39–25.89 (spherical) | MCF-7 | 27.79 | [33] |
| *Solanumtrilobatum* | Seed coat | 41.90 (spherical) | MCF-7 | 30 | [34] |
| *Elephantopusscaber* | Peel | 59 (spherical and polygonal) | Colo-259 | 17.4 | [35] |
| *Zingiberofficinale* | seed | 20–51 (spherical) | HT-29 | 150.8 | [36] |
| *Chlorophytumborivilianum* | peel | 52 (spherical) | HT-29 | 7 | [37] |
| *Oleachrysophylla, Lavandula dentate* | Aerial parts | 328.6–284.5 (spherical) | HCT116 | 99.35 | [38] |

| Plant used | Part used | Size (nm) and shape of AgNPs | Cancer cell line | $IC_{50}$ value (μg ml − 1) | Reference |
|---|---|---|---|---|---|
| *Mentha arvensis* | Leaves | 100 (spherical) | HCT116 | 1.7 | [39] |
| *Zanthoxylumrhesta* | Leaves | 10–68 (spherical) | A549 | 65.17 | [40] |
| *Punicagranatum* | leaves | 6–45 (spherical) | A549 | 5 | [41] |
| *Derris trifoliate* | leaves | 16.92 (spherical) | A549 | 86.23 | [42] |
| *Dimocarpuslonganlour* | Peel | 8–22 (spherical) | H1299 | 5.33 | [43] |
| *Neptadeflersiana* | Aerial parts | 33 (cubical) | HeLa | 23 | [44] |
| *Detariummicrocarpum* | Leaf | 81 (cubical) | HeLa, PANC-1 | 31.5–1.84 | [45] |
| *Ginkgo biloba* | leaf | 40 (spherical) | HeLa, SiHa | Dose dependent | [46] |
| *Rhizophoraapiculata* | leaf | >100 (spherical) | HEK-293, HeLa | 0.062–1.98 | [47] |
| *Punicagranatum* | leaf | 46.1 (spherical) | HeLa | 100 | [41] |
| *Allium sativum* | leaf | 100–800 (spherical) | HePG2 | 31.25 | [48] |
| *Biergavuaerecta* | leaf | 15.9 (spherical) | PA-1 | 25 | [46] |
| *Alternantherasessilis* | Whole plant | 30–50 (spherical) | PC3 | 6.8 | [49] |
| *Dimocarpuslongan* | Peel | 9–32 (cubical) | PC3 | 10 | [43] |
| *Perillafrutescens* | Leaf | 25.71 (spherical and cubical) | COLO205, LNCaP | 39.28–24.33 | [50] |
| *Salvia miltiorrhiza* | leaf | 100 (spherical and hexagonal) | LNCaP | 50 | [51] |
| *Zingiber officinale* | Leaf | 18.93 (spherical) | AsPC-1PANC-1 | 312–1295 | [36] |
| *Punicagranatum* | leaf | 35–69 (spherical) | HePG2 | 70 | [41] |
| *Elephantopusscaber* | leaf | 59 (spherical) | MCF-7, A-549 and SCC-40 | 10 | [35] |
| *Tamarindus indica* | Fruit shell | 20–30 (spherical) | MCF-7 | 120 | [24] |
| *Chaetomorphalinum* | | Smaller size (spherical) | HCT-116 | 48.84 | [52] |
| *Andrographis paniculata* | Stem | Small size u-shaped | Vero cells | 31.25 | [53] |
| *Phyllanthus niruri* | Leaf | | | 125 | |
| *Tinospora cordifolia* | Leaf | | | 250 | |
| *Conocarpus Lancifolius* | Fruits | 21 to 173 nm | MDA MB-231 | 16.8 μg/ml. | [54] |
| *Tridax procumbens* | Leaf | 11.1–45.4 | A459 | 42.70 | [55] |
| *Sambucus ebulus* | Leaf | 35–50 | AGS and MCF-7 | 240 | [56] |
| *Parthenium hysterophorus* | Leaf | 20 spherical | HepG2 | 50 | [57] |
| *Cleome viscosa* | leaf | 20–50 | A549 and PA1 | 28 and 30 μg/mL | [58] |
| Bee pollens | Leaf | 44 | MCF-7 | 90 | [59] |
| chitosan, | Leaf | 23 | MDA-MB–231 | 4.6 | [60] |

| Plant used | Part used | Size (nm) and shape of AgNPs | Cancer cell line | $IC_{50}$ value (μg ml − 1) | Reference |
|---|---|---|---|---|---|
| *Mimusops elengi* | Fruit | 43 spherical shape | HT-29 and MCF7 | 155 and 179 | [61] |
| *Gloriosa superba* | Stem | 7nm–14 spherical | A549 | 46.54 | [62] |
| *Luffa acutangula*, | Leaves | 8 spherical | MCF-7 | 90 | [63] |
| | | | MDA-MB-231 | 65 | |
| | | | U87 | 80 | |
| | | | DBTRG, | 90 | |
| *(Pistacia terebinthus)* | Leaves | 32 spherical shape | MCF-7 | 25 | [58] |
| *Hypericum Perforatum* | Leaves | 100 | HeLa | 7.71 | [64] |
| | | | Hep G2 | 12.44 | |
| *Alternanthera sessilis* | Aerial part | 10–30 nm/ spherical | MCF-7 | 3.04 | [65] |
| *Alternanthera tenella* | Leaf | 48 nm/– | MCF-7 | 42.5 | [55] |
| *Andrographis echioides* | Leaf | 68.06 nm/cubic, pentagonal, hexagona | MCF-7 | 31.5 | [65] |
| *Achillea biebersteinii* | Flower | 12 nm/spherical, pentagonal | MCF-7 | 20 μg/mL | [66] |
| *Azadirachta indica* | Leaf | 40 nm/spherical | MCF-7 | 10 | [59] |
| *oriandrum sativum* | Leaf | 37 nm/spherical, rod, triangular, hexagonal | MCF-7 | 30.5 | [67] |
| *Citrullus colocynthis* | Leaf | 7.39 nm/spherical | MCF-7 | 2.4 μg/mL | [68] |
| *Dendrophthoe falcata* | Leaf | 5–45 nm/spherical | MCF-7 | 7 | [57] |
| *Erythrina indica* | Root | 20–118 nm/ spherical | MCF-7 | 23.89 | [60] |
| *Melia dubia* | Leaf | 7.3 nm/irregular | MCF-7 | 31.2 | [69] |
| *Olax scandens* | | 30–60 nm/ spherical | MCF-7 | 30 | [70] |
| *Piper longum* | Root | 46 nm/spherical | MCF-7 | 67 | [71] |
| *Quercus (genus)* | Fruit hull | 46 spherical | MCF-7 | 50 | [34] |
| *Rheum emodi* | Root | 27.5 nm/spherical | MCF-7 | 28 | [47] |
| *Sesbania grandiflora* | Leaf | 22 nm/spherical | MCF-7 | 20 | [72] |
| *Solanum trilobatum* | fruit | 41.90 nm/ spherical, polygonal | MCF-7 | 30 | [46] |
| *Syzygium cumini* | Fruit | 40 nm/spherical | MCF-7 | 10 | [73] |
| *Syzygium aromaticum* | Fruit | 5–20 nm/spherical | MCF-7 | 70 | [74] |
| *Tabernae montana divaricate* | Leaf | Mean 22.85 nm/ spherica | MCF-7 | 20 | [75] |

| Plant used | Part used | Size (nm) and shape of AgNPs | Cancer cell line | $IC_{50}$ value (μg ml − 1) | Reference |
|---|---|---|---|---|---|
| *Taxus baccata* | Needles | Mean 75.1 nm/ spherical | MCF-7 | 0.25 | [76] |
| *Ulva lactuca* | Whole | 56 nm/spherica | MCF-7 | 37 | [71] |
| *Butea monosperma* | LEAF | 20–80 nm/ spherical | HNGC2 | 67 | |
| *Azadirachta indica* | Leaf | 2–18 nm/ triangular, hexagonal | shia | 4.1 | [77] |
| *Melia azedarach* | Leaf | 78 nm/cubical, spherical | HeLa | 300 | [78] |
| *Citrullus colocynthis* | Leaf | 16.57 nm/Spherical | HCT-116 | 30 | [79] |
| *Gymnema sylvestre* | Leaf | Spherical | HT29 | 85 | [80] |

*Key: A-549; H1299; lung cancer, MCF-7, MDA-MB-231; breast cancer cell lines, SCC-40; oral cancer, HCT-116, HT-29; colon cancer, PANC-1; pancreatic cancer, Bladder (5637); bladder cancer, HeLa & SiHa; cervical cancer, HEK-293; human embryonic kidney cells, HepG2; liver cancer, PA-1; ovarian teratocarcinoma cell, PC3; prostate cancer, and LNCaP; prostate adenocarcinoma.*

**Table 1.**
*Anticancer activities of silver nanoparticles (AgNPs) synthesized from plants.*

HCT116 colon cancer cells in human by inhibiting the cell division and reducing G1 phase [18]. In another study green synthesized AgNPs by using plant extract showed potent cytotoxicity against lung cancer [23]. AgNPs synthesized from fruit of *Tamarindus indica* and *Nepeta deflersiana* resulted into apoptosis and cytotoxicity for human breast cancer and cervical cancer, respectively. A dose dependent anticancer effect was observed may be induced due to oxidative stress that leads to mitochondrial and DNA impairment [24]. Cell lines from liver, gastric, and prostate cancer showed cytotoxic effects against AgNPs from lotus plants [26]. AgNPs prepared from *Crataegus microphylla* (fruit) and *Gossypium hirsutum* (leaf) showed considerable distortion of gastric adenocarcinoma cells [81]. It has been reported that AgNPs target the lung adenocarcinoma cells breaking DNA helix, chromosomal instability, and damage the mitochondria of cancerous cells [81]. When AgNPs applied to MCF-7, it changes the morphological parameter modifications, inhibition of cell growth and significant loss of plasma membrane integrity.

Although AgNPs of large size >100 nm can be more effective but small size <10 nm penetrate the cell, get localized inside the nucleus easily and can induce cytotoxicity at greater level as reported by Avalos et al. that smaller size nanoparticles exhibit more cytotoxicity than larger size in MTT assay and lactate dehydrogenase assays [82]. The mechanism involved behind inducing cytotoxicity is (i) interruption in cellular respiration and DNA replication due to uptake of free silver ions (ii) production of free silver radicals and reactive oxygen species (ROS) (iii) damage to cell membrane [83]. AgNPs induce ROS production and reduce glutathione (SGH), nuclear factor kB (NF-kB) and tumor necrosis factor-alpha (TNF-1) levels within cells). Increasing levels of superoxide radicals disrupt the mitochondrial signal transduction pathway, resulting in apoptosis [84]. The increase level of reactive oxygen species and decrease glutathione elicit damage to different components of cell such as breaking of DNA, peroxidation of lipid membrane and protein

carbonylation. Apoptosis occurs when caspases 3 and 9 are activated as a result of changing mitochondrial membrane potential**.** After that, it activates c-Jun NH2terminal kinase (JNK), which causes DNA breaks to cause cell cycle arrest and the creation of apoptotic bodies [85]. AgNPs prepared from plants increase the sub-G1 phases of cell cycle and exhibit potent cytotoxicity. Chang et al. demonstrated link between sub-G1 arrests in cancer cells treated with curcumin showed more apoptosis suggested that AgNPs induced apoptosis in cancerous cells by prolonged sub-G1 phase [86]. This implies that the enhanced sub-G1 arrest of cancerous cells, which is connected to the induction of apoptosis, may be resulting in the death of cancer cells due to AgNPs application. In addition, green synthesized AgNPs prevented the formation of new cells induced by vascular endothelial growth factor (VEGF). After penetrating into the cell, AgNPs inhibited VEGF and through Src-dependent pathway the vascular permeability 1 L-1βinduced occured. [87]. Due to this anti-angiogenic efficacy AgNPs recommended as a new gateway of treatment for cancer. Another mechanism suggested for the anticancer potential of AgNPs is autophagy-induced cell breakdown, which results in cell death. Additionally, because autophagolysosomes accumulate in cancer cells and are more prevalent there, greenly produced AgNPs encourage autophagy, which ultimately results in cell death [30].

### 2.2 Silver nanoparticles as antibacterial agent

Silver nanoparticles have antibacterial properties and they auspiciously appear to be more potent and efficient antimicrobial agents than other nanomaterials from noble metals, due to their unique properties such as a large surface to volume ratio, toxicity, interaction with phosphorus and sulfur compounds in the cell [88]. These characteristics make them excellent agents for treating a variety of microbial infectious complaints, as well as for overcoming microbial resistance to conventional medicines, whether used in single or in combination with other therapeutic formulations [89]. The synergistic action of nano-silver and a broad variety of phytoconstituents exhibit wide range of antibacterial qualities, as silver nanoparticles are easily manufactured from plant extracts with extraordinary stability and eco-friendly approach. According to a report antimicrobial agent containing silver ions can damage the external membrane of targeted cell by reacting with proteins (thiol group) resulted in inactivation of bacterial enzymes. Silver reduces DNA replication and uncouples electron transport from oxidative phosphorylation when applied. As a result it interferes with membrane permeability and inhibits the respiratory chain enzymes and kills the microbes at very low concentration [90, 91]. AgNPs have suppressed the growth of bacteria at the minimum inhibitory concentration (MIC) for example; *Cestrum nocturnum*at at 0.25 μg/ml concentration showed 36 mm zone of inhibition against *Citrobecter* which support the above statement. At a dosage of 10 μg/ml, *B. vulgaris* and *B. nigra* demonstrated substantial antibacterial activity against *S. aureus* (93 mm) while *Ceratonia siliqua* leaves showed 8 mm inhibitory zone against *E. coli* (**Table 1**). *Ocimum sanctum* at 5 μg/ml concentration showed 11 mm zone of inhibition against *E. coli.* When tested at minimum inhibitory concentrations, AgNPs showed excellent permeability through bacterial cell walls and plasma membranes. AgNPs interacting with plasma membranes and releasing Ag + ions into cell cytoplasm, Thus, respiratory mechanisms and ion exchange processes were disrupted in bacterial membranes and mesosomes, and the obstruction of sulfur-containing protein synthesis on ribosomes [92]. When biologically produced nanoparticles and

$AgNO_3$ solutions were combined, the cytotoxic action was enhanced [93]. The addition of Ag + ions to the culture media reduced the production of biofilms by bacteria during growth. In biological experiments, AgNPs were found to have anti-biofilm formation properties against Gram positive (*Enterococcus faecalis* and *S. aureus*) and Gram negative (*Shigella sonnei* and *Pseudomonas aeruginosa*) [94]. All of these mechanisms of action show that AgNPs have antibacterial capabilities and that they can be used as anti-pathogenic drugs to reduce microorganism proliferation (**Table 2**).

| Plant used | Concentration (μg/ml) | Bacteria | ZI (mm) | Reference |
|---|---|---|---|---|
| *Coptis chinensis* | 12.50 | *E. coli* | 12 | [95] |
| *Cestrum nocturnum* | 0.25 | *Citrobacter* | 36 | [94] |
| | 1 | *S. typhi* | 28 | |
| | 2 | *E. faecalis* | 15 | |
| | 4 | *E. coli* | 23 | |
| | 8 | *P. vulgaris* | 26 | |
| | 16 | *V. cholerae* | 41 | |
| *B. vulgaris* | 10 | *P. aeruginosa* | 77.57 | [96] |
| | | *E. coli* | 89.21 | |
| | | *S. aureus* | 93.64 | |
| *B. nigar* | 10 | *P. aeruginosa* | 73.83 | |
| | | *E. coli* | 83.31 | |
| | | *S. aureus* | 93.12 | |
| *C. burspastoris* | 15.50 | *P. aeruginosa* | 92.62 | |
| | | *E. coli* | 80.76 | |
| | | *S. aureus* | 96.03 | |
| *Ceratonia siliqua* | 10 | *E. coli* | 8 | [97] |
| *Helictere sisora* | 12.5 | *E. coli* | 2 | [98] |
| | 100 | *V. cholerae* | 6 | |
| *Ocimum sanctum* | 5 | *E. coli* | 11 | [99] |
| | | *S. aureus* | 10 | |
| *Acalypha indica* | 10 | *E. coli* | | [100] |
| *Citrus aurantiifolia* | | *E. coli* | 7 | [101] |
| *Citrus sinensis* | | | 8 | |
| *Citrus limetta* | | | 6 | |
| *Citrus aurantiifolia* | | *K. pneumoniae* | 6 | |
| *Citrus sinensis* | | | 8 | |
| *Citrus limetta* | | | 5 | |
| *Citrus aurantiifolia* | | *S. aureus* | 5 | |
| *Citrus sinensis* | | | 5 | |
| *Citrus limetta* | | | 4 | |

| Plant used | Concentration (μg/ml) | Bacteria | ZI (mm) | Reference |
|---|---|---|---|---|
| *Citrus aurantiifolia* | | *S. typhimurium* | 6 | |
| *Citrus sinensis* | | | 6 | |
| *Citrus limetta* | | | 4 | |
| *Zingiber officinale* | 100 | *Staphylococcus spp* | 6.5 | [102] |
| *Coffea arabica* | 0.05 | *E. coli* | 2.3 | [103] |
| | 0.1 | | 3.1 | |
| | 0.05 | *S. aureus* | 2.1 | |
| | 0.1 | | 2.7 | |
| *Chlorophytum borivilianum* | 15 | *S. aureus* | 10 | [37] |
| | 30 | | 17 | |
| | 60 | | 29 | |
| | 15 | *P. aeruginosa* | 9 | |
| | 30 | | 11 | |
| | 60 | | 14 | |
| *Ficus sycomorus* | 50 | *E. coli* | 9 | [104] |
| | | *S. aureus* | 11 | |
| | | *P. aeruginosa* | 11 | |
| | | *K. pneumoniae* | 18 | |
| | | *S. typhi* | 30 | |
| | | *S. flexneri* | 16 | |
| *Zataria multiflora* | 20 | *S. aureus* | | [105] |
| | | *P. aeruginosa* | | |
| *Malva verticillata* | 100 | *A. hydrophila n* | 12.44 | [106] |
| | | *A. salmonicida* | 28.64 | |
| *Camilla sinensis* | 50 | *E. coli* | 12.5 | [107] |
| *Rhizophora apiculata* | 21 | *B. subtilis* | 11 | [108] |
| | | *E. coli* | 14 | |
| | | *K. pneumoniae* | 14 | |
| | | *P. vulgaris* | 14 | |
| | | *P. aeruginosa* | 12 | |
| | | *S. typhi* | 14 | |
| *Dryopteris crassirhizoma* | 100 | *B. cereus* | 2 | [109] |
| | 150 | *P. aeruginosa* | 3 | |
| *Acacia leucophloea* | 25 | *S. aureus* | 15 | [110] |
| | 50 | *B. cereus* | 17.50 | |
| | 75 | *S. flexneri* | 17 | |
| *Olea europaea* | 7 | *S. aureus* | 2.7 | [111] |

| Plant used | Concentration (μg/ml) | Bacteria | ZI (mm) | Reference |
|---|---|---|---|---|
| *Conocarpus Lancifolius* | 2.5 | *s. aureus* | 4 | [54] |
| | 5 | | 7.5 | |
| | 10 | | 11 | |
| | 20 | | 14 | |
| | 50 | | 22 | |
| | 2.5 | *s. pneumoniae* | 3.8 | |
| | 5 | | 7 | |
| | 10 | | 10 | |
| | 20 | | 11 | |
| | 50 | | 19 | |
| *Tridax procumbens* | 20 | *E. coli* | 11 | [55] |
| | | *Shigella. ssp* | 15 | |
| | | *Pseudomonas aeruginosa* | 20.66 | |
| | | *Pseudomonas aeruginosa* | 15.33 | |
| | | *Candida tropicalis* | 20 | |
| *Cleome viscosa* | 10 | *s. aureus* | 11 | [101] |
| | 20 | | 13 | |
| | 30 | | 14 | |
| | 40 | | 17 | |
| | 10 | *B. subtilis* | 10 | |
| | 20 | | 12 | |
| | 30 | | 13 | |
| | 40 | | 14 | |
| | 10 | *E. coli* | 10 | |
| | 20 | | 13 | |
| | 30 | | 15 | |
| | 40 | | 16 | |
| *Bee pollen* | 100 μg/mL | *B. subtilis* | 18 | [59] |
| | | *P. aeruginosa* | 18 | |
| | | *S. aureus* | 17 | |
| | | *E. coli* | 11 | |
| *Parthenium hysterophorus* | 60 | *E. coli* | 17 | [60] |
| | | *P. aeruginosa* | 18 | |
| | | *B. subtilis* | 12 | |
| | | *E. feacali* | 11 | |
| | | *S. aureus* | 15 | |

| Plant used | Concentration (μg/ml) | Bacteria | ZI (mm) | Reference |
|---|---|---|---|---|
| *Gloriosa superba* | 40 | *Enterococcus faecalis* | 29 | [62] |
| | | *Bacillus subtilis* | 24 | |
| | | *Staphylococcus aureus* | 23 | |
| *Luffa acutangula* | 5 | *B. subtilis* | 7.2 | [63] |
| | | *S. aureus* | 7.9 | |
| | | *E. coli* | 7.4 | |
| *P. americana* | 25 | *P. vermicola* | 24 | [102] |
| | | *A. caviae* | 17 | |
| | 50 | *E. coli* | 10 | [103] |
| | | *Bacillus subtilis* | 8 | |
| *Taxus baccata* Linn | 25 | *Shigella dysenteriae* | 10 | [77] |
| | | *E. coli* | 12 | |
| | | *Salmonella typhi* | 08 | |
| *Gardenia thailandica* | 50 | *S. aureus* | 12 | [103] |

**Table 2.**
*Antibacterial activity of silver nanoparticles (AgNPs) from plants.*

## 2.3 Antifungal activity of silver Nano particles

Drug resistance by pathogenic fungi has been continuously increasing, so it is necessary to develop new antifungal agent. The antifungal agent was present in the form of the chemically, physically and, biologically. The green plants which caring affective metabolites and particles which use against the fungus disease. There are the many nano particles which use against the fungi but Silver nano particles have the drastic affect against the many disease which is caused by the fungi [25]. In many study reported that the AgNPs as antifungal agent in treating fungal infectious diseases [112]. This disease badly affected the human and the plants as well. Silver nanoparticle are very effective against the four pathogens *R. solani, F. oxysporum, S. sclerotiorum,* and *S. rolfsii* which caused the disease in the vegetable and horticulture. Silver nanoparticles activity was checked at the four different concentration against these fungus species [113]. Silver nano particles was seen the most activity against the candida albican species include *C. tropicalis*, *C. glabrata*, *C. parapsilosis. C. glabrata* at different concentration (0.01 μg −300 μg) with different zone of inhibitions (05–70) [114] (**Table 3**).

| Plant name | Concentration μg | Fungus | | Reference |
|---|---|---|---|---|
| *Garcinia kola* pulp | 75 | *Candida tropicalis* | 13 | [115] |
| | | *Fusarium oxysperium* | 15 | |
| *Taxus baccata* Linn | 90 | *T. purpureogenus* | 22 | [77] |
| *Juniperus procera* | 50 | *C. albicans* ATCC885653 | 14.3 | |
| | 50 | *C. neoformans* ATCC16620 | 9.80 | |

| Plant name | Concentration µg | Fungus | | Reference |
|---|---|---|---|---|
| red curran | 30 | *Fusarium oxysporum* | 12 | [116] |
| | | *Botrytis cinerea* | 26 | |
| | | *Pestalotiopsis mangiferae* | 50 | |
| *E. tirucalli* | 923.4 | *B. cinérea* | 1.9 | [117] |
| | | *R. stolonifera* | 3.5 | |
| *B. lanzan* Spreng | 50 ppm | *Rhizoctonia solani*. | 47 | [118] |
| | 100 ppm | | 52 | |
| *Allium fistulosum* | 0.32 mg/mL | *Aspergillus niger* | 08 | [119] |
| | 10 mg/mL | | 11 | |
| | 0.32 mg/mL | *Candida albicans* | 07 | |
| | 10 mg/mL | | 10 | |
| *Cynara cardunculus* | 1.8 mg/mL | *C. albicans* | 26.6 | [120] |
| *Glycosmis pentaphylla* | 11 | *A. alternata* | 15.5 | [121] |
| | | *F. moniliforme* | 14.5 | |
| | | *Colletotrichum lindemuthianum* | 9.5 | |
| | | *Candida glabrat* | 12 | |
| *O. vulgare* | 5 µL | *Aspergillus flavus* | 7.7 | [122] |
| | 10 µL | | 11 | |
| | 5 µL | *Fusarium moniliform* | 7 | |
| | 10 µL | | 10 | |
| | 5 µL | *Candida albicans* | 10 | |
| | 10 µL | | 18 | |
| *Borago officinalis* | 100 | *Candida albicans* | 7 | [123] |
| *Alhagi graecorum* | 0.01 mmol\ml | *C. albicans* | 14 | [124] |
| | | *C. glabrata* | 18 | |
| | | *C. parapsilosis* | 22 | |
| | | *C. tropicales* | 21 | |
| | | *C. krusei* | 15 | |
| | 0.02 mmol\ml | *C. albicans* | 16 | |
| | | *C. glabrata* | 21 | |
| | | *C. parapsilosis* | 27 | |
| | | *C. tropicales* | 25 | |
| | | *C. krusei* | 17 | |
| *Malva parviflora L* | 15 µg /mL | *F. solani* | 81.1 | [125] |
| | | *A. alternata* | 83 | |
| | | *H. rostratum* | 88.6 | |
| | | *F. oxysporum* | 80 | |

| Plant name | Concentration µg | Fungus | | Reference |
|---|---|---|---|---|
| *Allium ampeloprasum* | 25 µg /mL | *C. albicans* | 20.1 | [126] |
| | | *C. glabrata* | 20.6 | |
| | | *C. krusei* | 15.1 | |
| | | *C. tropicalis* | 16.4 | |
| | | *C. parapsilosis* | 18.4 | |
| *Melia azedarach* | 20 µg /mL | *Verticillium dahliae* | 87 | [127] |
| *Teucrium polium* L | 50 µg /mL | *F. oxysporum* | 46 | [128] |
| | 100 µg /mL | | 54 | |
| | 150 µg /mL | | 54 | |
| plant essential oil | 20 µg /mL | *Aspergillus niger* | 11.33 | [129] |
| | 20 µg /mL | *Aspergillus flavus* | 13.27 | |
| | | *Candida albicans* | 9.87 | |
| | | *Candida tropicalis* | 14.66 | |
| | | *Candida kefyr* | 15.17 | |
| maize | 25 | *C. albicans* | 0.021 | [130] |
| Maize | 47 g | *Candida albicans* | 62.5 | [131] |
| *Ferulago macrocarpa* | 250 µg/mL | *Candida albicans* | 34 | [132] |
| *Lotus lalambensis* | 6.25 | *Candida albicans* | 10 | [133] |
| | 12.5 | | 13 | |
| | 25 | | 16 | |
| | 50 | | 19 | |
| Grass waste | 2 | *F. solani* | 20 | [134] |
| | 5 | | 38 | |
| | 10 | | 60 | |

**Table 3.**
*Antifungal activity of silver nanoparticles (AgNPs) from plants.*

## 3. Conclusions

Due to the vast range of activities and unique physical and chemical characteristics, silver nanoparticles are currently the subject of in-depth research. AgNPs are effective anticancer agents because they affect the cell cycle, prevent the growth of cancer cells, cause oxidative stress, and promote apoptosis [135, 136]. They protect against bacterial infections and showed potent antibacterial effect at minute concentrations. Due to the weakened immunological resistance of cancer patients, such antimicrobial protection is preferred during chemo- and radiotherapy. Most of the literature for use of AgNPs as antibacterial and anticancer agent is quite reported recently in present century showing that nanomedicine has made many advances in ongoing years and still there need to explored this field [137–139]. In order to gain unique insights and improve silver NP characteristics, additional research on AgNPs needs to be done.

Future applications may involve certain contentious concerns, like dose for various tissues; side effects from therapy, tissue-specific biocompatibility, or microbial resistance to NPs. AgNPs have some actions that seem to be dual or even contradictory depending on the situation. Examples include anti- or pro-oxidative, biosensing or bioresisting activity depending on the type of cell or living organism. Before being added to cells, NPs must be thoroughly described and their physical and chemical characteristics must be understood. These characteristics are mostly the product of various AgNP synthesis techniques, and only nontoxic ones should be favored in bioassays involving living models.

## Author contributions

Muhammad Adnan and Ruqia Nazir, Sakina Mussarat conceived the idea of chapter, helped in writing and provide useful suggestions. Sakina Mussarat and Attique ur Rehman Khan participated in writing of the manuscript, and performed all literature surveys, designed the figures and reviewed the literature. All authors were involved in revising the chapter content, read, and approved the final draft.

## Conflict of interest

The authors declared no potential conflicts of interest.

## Author details

Attique Ur Rehman Khan[1*†], Muhammad Adnan[2*†], Shaheen Begum[3], Ruqia Nazir[1] and Sakina Mussarat[2†]

1 Department of Chemistry, Kohat University of Science and Technology, Kohat, Pakistan

2 Department of Botany, Kohat University of Science and Technology, Kohat, Pakistan

3 Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi, Pakistan

*Address all correspondence to: atteeqrehmankhan78@gmail.com and ghurzang@hotmail.com

† These authors contributed equally.

## References

[1] Russell A, Hugo W. 7 antimicrobial activity and action of silver. Progress in Medicinal Chemistry. 1994;**31**:351-370

[2] Jamieson WE, Fradet GJ, Abel JG, Janusz MT, Lichtenstein SV, MacNab JS, et al. Seven-year results with the St Jude Medical Silzone mechanical prosthesis. The Journal of Thoracic and Cardiovascular Surgery. 2009;**137**(5): 1109-1115. e1102

[3] Ge L, Li Q, Wang M, Ouyang J, Li X, Xing MM. Nanosilver particles in medical applications: Synthesis, performance, and toxicity. International Journal of Nanomedicine. 2014;**9**:2399

[4] Farokhzad OC, Langer R. Impact of nanotechnology on drug delivery. ACS Nano. 2009;**3**(1):16-20

[5] Tadele KT, Abire TO, Feyisa TY. Green synthesized silver nanoparticles using plant extracts as promising prospect for cancer therapy: A review of recent findings. Journal of Nanomedicine. 2021;**4**:1040

[6] Jha M, Shimpi NG. Green synthesis of zero valent colloidal nanosilver targeting A549 lung cancer cell: in vitro cytotoxicity. Journal of Genetic Engineering and Biotechnology. 2018;**16**(1):115-124

[7] Skonieczna M, Hudy D. Biological Activity of Silver Nanoparticles and Their Applications in Anticancer Therapy. London, UK, London: IntechOpen; 2018

[8] Choi S, Kim KS, Yeon SH, Cha JH, Lee H, Kim CJ, et al. Fabrication of silver nanoparticles via self-regulated reduction by 1-(2-hydroxyethyl)-3-methylimidazolium tetrafluoroborate. Korean Journal of Chemical Engineering. 2007;**24**(5):856-859

[9] Park Y et al. A new paradigm shift for the green synthesis of antibacterial silver nanoparticles utilizing plant extracts. Toxicological Research. 2014;**30**(3): 169-178

[10] Li X, Xu H, Zhe-Sheng C, et al. Biosynthesis of nanoparticles by microorganisms and their applications. Journal of Nanomaterials. 2011;**11**:1-16

[11] Abou El-Nour KM et al. Synthesis and applications of silver nanoparticles. Arabian Journal of Chemistry. 2010;**3**(3): 135-140

[12] Jung J, Oh H, Noh H, Ji J, Kim S. Metal nanoparticle generation using a small ceramic heater with a local heating area. Journal of Aerosol Science. 2006; **37**(1):662-167

[13] Ahmed KBR, Nagy AM, Brown RP, Zhang Q, Malghan SG, Goering PL. Silver nanoparticles: Significance of physicochemical properties and assay interference on the interpretation of in vitro cytotoxicity studies. Toxicology In Vitro. 2017;**38**:179-192

[14] Bouwmeester H, Dekkers S, Noordam MY, Hagens WI, Bulder AS, De Heer C, et al. Review of health safety aspects of nanotechnologies in food production. Regulatory Toxicology and Pharmacology. 2009; **53**(1):52-62

[15] Aueviriyavit S, Phummiratch D, Maniratanachote R. Mechanistic study on the biological effects of silver and gold nanoparticles in Caco-2 cells–induction of the Nrf2/HO-1 pathway by high concentrations of silver nanoparticles. Toxicology Letters. 2014; **224**(1):73-83

[16] Rai M, Ingle AP, Birla S, Yadav A, Santos CAD. Strategic role of selected noble metal nanoparticles in medicine. Critical Reviews in Microbiology. 2016; **42**(5):696-719

[17] Mfouo-Tynga I, El-Hussein A, Abdel-Harith M, Abrahamse H. Photodynamic ability of silver nanoparticles in inducing cytotoxic effects in breast and lung cancer cell lines. International Journal of Nanomedicine. 2014;**9**(1):3771-3780

[18] El-Hussein A, Hamblin MR. ROS generation and DNA damage with photo-inactivation mediated by silver nanoparticles in lung cancer cell line. IET Nanobiotechnology. 2017;**11**(2):173-178

[19] Hudecki A, Gola J, Ghavami S, Skonieczna M, Markowski J, Likus W, et al. Structure and properties of slow-resorbing nanofibers obtained by (co-axial) electrospinning as tissue scaffolds in regenerative medicine. PeerJournal. 2017;**5**:e4125

[20] Deng H, McShan D, Zhang Y, Sinha SS, Arslan Z, Ray PC, et al. Mechanistic study of the synergistic antibacterial activity of combined silver nanoparticles and common antibiotics. Environmental Science & Technology. 2016;**50**(16):8840-8848

[21] Calderón-Jiménez B, Johnson ME, Montoro Bustos AR, Murphy KE, Winchester MR, Vega Baudrit JR. Silver nanoparticles: Technological advances, societal impacts, and metrological challenges. Frontiers in Chemistry. 2017; **5**:6

[22] Rafique M, Rafique MS, Kalsoom U, Afzal A, Butt SH, Usman A. Laser ablation synthesis of silver nanoparticles in water and dependence on laser nature. Optical and Quantum Electronics. 2019; **51**(6):1-11

[23] Javed B, Nadhman A, Razzaq A. One-pot phytosynthesis of nano-silver from Mentha longifolia L.: Their characterization and evaluation of photodynamic potential. Materials Research Express. 2020;**7**(5):055401

[24] Jabeen S, Qureshi R, Munazir M, Maqsood M, Munir M, Shah SH, et al. Application of green synthesized silver nanoparticles in cancer treatment-a critical review. Materials Research Express. 2021

[25] Kowsalya E, MosaChristas K, Balashanmugam P, Rani JC. Biocompatible silver nanoparticles/poly (vinyl alcohol) electrospun nanofibers for potential antimicrobial food packaging applications. Food Packaging and Shelf Life. 2019;**21**(7):100-379

[26] Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: a Cancer Journal for Clinicians. 2021;**71**(3): 209-249

[27] Tian S, Saravanan K, Mothana RA, Ramachandran G, Rajivgandhi G, Manoharan N. Anti-cancer activity of biosynthesized silver nanoparticles using Avicennia marina against A549 lung cancer cells through ROS/mitochondrial damages. Saudi Journal of Biological Sciences. 2020;**27**(11):3018-3024

[28] Iqbal MJ, Ali S, Rashid U, Kamran M, Malik MF, Sughra K, et al. Biosynthesis of silver nanoparticles from leaf extract of Litchi chinensis and its dynamic biological impact on microbial cells and human cancer cell lines. Cellular and Molecular Biology. 2018;**64**(13):42-47

[29] Gurunathan S, Raman J, Abd Malek SN, John PA, Vikineswary S.

Green synthesis of silver nanoparticles using Ganoderma neo-japonicum Imazeki: A potential cytotoxic agent against breast cancer cells. International Journal of Nanomedicine. 2013;**8**:4399

[30] Balkrishna A, Sharma VK, Das SK, Mishra N, Bisht L, Joshi A, et al. Characterization and anti-cancerous effect of Putranjiva roxburghii seed extract mediated silver nanoparticles on human colon (HCT-116), pancreatic (PANC-1) and breast (MDA-MB 231) cancer cell lines: A comparative study. International Journal of Nanomedicine. 2020;**15**:573

[31] Elhawary S, Hala E-H, Mokhtar FA, Mansour Sobeh EM, Osman S, El-Raey M. Green synthesis of silver nanoparticles using extract of Jasminum officinal l. leaves and evaluation of cytotoxic activity towards bladder (5637) and breast cancer (MCF-7) cell lines. International Journal of Nanomedicine. 2020;**15**:9771

[32] Elgamouz A, Idriss H, Nassab C, Bihi A, Bajou K, Hasan K, et al. Green synthesis, characterization, antimicrobial, anti-cancer, and optimization of colorimetric sensing of hydrogen peroxide of algae extract capped silver nanoparticles. Nanomaterials. 2020;**10**(9):1861

[33] El-Naggar NE-A, Hussein MH, El-Sawah AA. Bio-fabrication of silver nanoparticles by phycocyanin, characterization, in vitro anticancer activity against breast cancer cell line and in vivo cytotxicity. Scientific Reports. 2017;**7**(1):1-20

[34] Ramar M, Manikandan B, Marimuthu PN, Raman T, Mahalingam A, Subramanian P, et al. Synthesis of silver nanoparticles using Solanum trilobatum fruits extract and its antibacterial, cytotoxic activity against human breast cancer cell line MCF 7. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2015; **140**:223-228

[35] Shinde AS, Mendhulkar V. Antiproliferative activity of Elephantopus scaber mediated silver nanoparticles against MCF-7, A-549, SCC-40 and COLO-205 human cancer cell lines. Asian Journal of Pharmaceutical and Clinical Research. 2020;**13**(2):163-167

[36] Venkatadri B, Shanparvish E, Rameshkumar M, Arasu MV, Al-Dhabi NA, Ponnusamy VK, et al. Green synthesis of silver nanoparticles using aqueous rhizome extract of Zingiber officinale and Curcuma longa: In-vitro anti-cancer potential on human colon carcinoma HT-29 cells. Saudi Journal of Biological Sciences. 2020;**27**(11): 2980-2986

[37] Huang F, Long Y, Liang Q, Purushotham B, Swamy MK, Duan Y. Safed Musli (Chlorophytum borivilianum L.) callus-mediated biosynthesis of silver nanoparticles and evaluation of their antimicrobial activity and cytotoxicity against human colon cancer cells. Journal of Nanomaterials. 2019;**2019**

[38] Sufyani A, Moslah N, Hussien NA, Hawsawi YM. Characterization and anticancer potential of silver nanoparticles biosynthesized from Olea chrysophylla and Lavandula dentata leaf extracts on HCT116 colon cancer cells. Journal of Nanomaterials. 2019;**2019**

[39] Banerjee PP, Bandyopadhyay A, Harsha SN, Policegoudra RS, Bhattacharya S, Karak N, et al. Mentha arvensis (Linn.)-mediated green silver nanoparticles trigger caspase 9-dependent cell death in MCF7 and MDA-

MB-231 cells. Breast Cancer: Targets and Therapy. 2017;**9**:265

[40] Nayaka S, Chakraborty B, Pallavi S, Bhat MP, Shashiraj K, Ghasti B. Synthesis of biogenic silver nanoparticles using Zanthoxylum rhetsa (Roxb.) DC seed coat extract as reducing agent and in-vitro assessment of anticancer effect on A549 lung cancer cell line. International Journal of Pharmaceutical Research. 2020;**12**(3):302-314

[41] Annu M, Ahmed S, Kaur G, Sharma P, Singh S, Ikram S. Evaluation of the antioxidant, antibacterial and anticancer (lung cancer cell line A549) activity of Punica granatum mediated silver nanoparticles. Toxicology Research. 2018;7(5):923-930

[42] Cyril N, George JB, Joseph L, Raghavamenon A, Vp S. Assessment of antioxidant, antibacterial and anti-proliferative (lung cancer cell line A549) activities of green synthesized silver nanoparticles from Derris trifoliata. Toxicology Research. 2019;**8**(2):297-308

[43] He Y, Du Z, Ma S, Cheng S, Jiang S, Liu Y, et al. Biosynthesis, antibacterial activity and anticancer effects against prostate cancer (PC-3) cells of silver nanoparticles using Dimocarpus Longan Lour. Peel extract. Nanoscale Research Letters. 2016;**11**(1):1-10

[44] Al-Sheddi ES, Farshori NN, Al-Oqail MM, Al-Massarani SM, Saquib Q, Wahab R, et al. Anticancer potential of green synthesized silver nanoparticles using extract of Nepeta deflersiana against human cervical cancer cells (HeLA). Bioinorganic Chemistry and Applications. 2018:1-12

[45] Adebayo IA, Arsad H, Gagman HA, Ismail NZ, Samian MR. Inhibitory effect of eco-friendly naturally synthesized silver nanoparticles from the leaf extract of medicinal Detarium microcarpum plant on pancreatic and cervical cancer cells. Asian Pacific journal of cancer prevention: APJCP. 2020;**21**(5):1247

[46] Xu Z, Feng Q, Wang M, Zhao H, Lin Y, Zhou S. Green biosynthesized silver nanoparticles with aqueous extracts of ginkgo biloba induce apoptosis via mitochondrial pathway in cervical cancer cells. Frontiers in Oncology. 2020;**10**:575415

[47] Liu X, Shan K, Shao X, Shi X, He Y, Liu Z, et al. Nanotoxic effects of silver nanoparticles on normal HEK-293 cells in comparison to cancerous HeLa cell line. International Journal of Nanomedicine. 2021;**16**:753

[48] Palle SR, Penchalaneni J, Lavudi K, Gaddam SA, Kotakadi VS, Challagundala VN. Green synthesis of silver nanoparticles by leaf extracts of boerhavia erecta and spectral characterization and their antimicrobial, antioxidant ad cytotoxic studies on ovarian cancer cell lines. Letters in Applied NanoBioScience. 2020;**9**: 1165-1176

[49] Firdhouse MJ, Lalitha P. Biosynthesis of silver nanoparticles using the extract of Alternanthera sessilis—Antiproliferative effect against prostate cancer cells. Cancer Nanotechnology. 2013;**4**(6):137-143

[50] Reddy N, Li H, Hou T, Bethu M, Ren Z, Zhang Z. Phytosynthesis of silver nanoparticles using Perilla frutescens leaf extract: Characterization and evaluation of antibacterial, antioxidant, and anticancer activities. International Journal of Nanomedicine. 2021;**16**:15

[51] Zhang K, Liu X, Samuel Ravi SOA, Ramachandran A, Aziz Ibrahim IA, Nassir AM, et al. Synthesis of silver nanoparticles (AgNPs) from leaf extract

of salvia miltiorrhiza and its anticancer potential in human prostate cancer LNCaP cell lines. Artificial Cells, Nanomedicine, and Biotechnology. 2019; **47**(1):2846-2854

[52] Acharya D, Satapathy S, Somu P, Parida UK, Mishra G. Apoptotic effect and anticancer activity of biosynthesized silver nanoparticles from marine algae Chaetomorpha linum extract against human colon cancer cell HCT-116. Biological Trace Element Research. 2021; **199**(5):1812-1822

[53] Sharma D et al. Antimicrobial and cytotoxic potential of silver nanoparticles synthesized using Rheum emodi roots extract. New Frontiers in Chemistry. 2015;**24**(2):121

[54] Oves M et al. Green synthesis of silver nanoparticles by Conocarpus Lancifolius plant extract and their antimicrobial and anticancer activities. Saudi Journal of Biological Sciences. 2022;**29**(1):460-471

[55] Pungle R et al. Green synthesis of silver nanoparticles using the Tridax procumbens plant extract and screening of its antimicrobial and anticancer activities. Oxidative Medicine and Cellular Longevity. 2022:1-14

[56] Hashemi Z et al. Sustainable green synthesis of silver nanoparticles using Sambucus ebulus phenolic extract (AgNPs@ SEE): Optimization and assessment of photocatalytic degradation of methyl orange and their in vitro antibacterial and anticancer activity. Arabian Journal of Chemistry. 2022; **15**(1):103525

[57] Ahsan A et al. Green synthesis of silver nanoparticles using Parthenium hysterophorus: Optimization, characterization and in vitro therapeutic evaluation. Molecules. 2020;**25**(15)

[58] Lakshmanan G et al. Plant-mediated synthesis of silver nanoparticles using fruit extract of Cleome viscosa L.: Assessment of their antibacterial and anticancer activity. Karbala International Journal of Modern Science. 2018;**4**(1): 61-68

[59] Al-Yousef HM et al. Pollen bee aqueous extract-based synthesis of silver nanoparticles and evaluation of their anti-cancer and anti-bacterial activities. PRO. 2020;**8**(5):52

[60] Venkatesan J et al. Antimicrobial and anticancer activities of porous chitosan-alginate biosynthesized silver nanoparticles. International Journal of Biological Macromolecules. 2017;**98**: 515-525

[61] Korkmaz N et al. Biogenic silver nanoparticles synthesized via Mimusops elengi fruit extract, a study on antibiofilm, antibacterial, and anticancer activities. Journal of Drug Delivery Science and Technology. 2020;**59**:101864

[62] Murugesan AK et al. Facile green synthesis and characterization of Gloriosa superba L. tuber extract-capped silver nanoparticles (GST-AgNPs) and its potential antibacterial and anticancer activities against A549 human cancer cells. Environmental Nanotechnology, Monitoring & Management. 2021;**15**: 100460

[63] Naghmachi M, Raissi A, Baziyar P, Homayoonfar F, Amirmahani F, Danaei M. Green synthesis of silver nanoparticles (AgNPs) by Pistacia terebinthus extract: Comprehensive evaluation of antimicrobial, antioxidant and anticancer effects. Biochemical and Biophysical Research Communications. 2022;**608**:163-169

[64] Firdhouse J, Lalitha P. Apoptotic efficacy of biogenic silver nanoparticles

on human breast cancer MCF-7 cell lines. Progress in Biomaterials. 2015;**4**:113

[65] Sathishkumar P et al. Phyto-synthesis of silver nanoparticles using Alternanthera tenella leaf extract: An effective inhibitor for the migration of human breast adenocarcinoma (MCF-7) cells. Bioprocess and Biosystems Engineering. 2016;**39**(4):651-659

[66] Sre PR et al. Antibacterial and cytotoxic effect of biologically synthesized silver nanoparticles using aqueous root extract of Erythrina indica lam. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2015;**135**:1137-1144

[67] Kathiravan V et al. Synthesis of silver nanoparticles from Melia dubia leaf extract and their in vitro anticancer activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2014;**130**:116-121

[68] Reddy N et al. Evaluation of antioxidant, antibacterial and cytotoxic effects of green synthesized silver nanoparticles by Piper longum fruit. Materials Science and Engineering: C. 2014;**34**:115-122

[69] Heydari R, Rashidipour M. Green synthesis of silver nanoparticles using extract of oak fruit hull (Jaft): Synthesis and in vitro cytotoxic effect on MCF-7 cells. International Journal of Breast Cancer. 2015:2015

[70] Jeyaraj M et al. Biogenic silver nanoparticles for cancer treatment: An experimental report. Colloids and Surfaces B: Biointerfaces. 2013;**106**:86-92

[71] Sathishkumar P et al. Anti-acne, anti-dandruff and anti-breast cancer efficacy of green synthesised silver nanoparticles using Coriandrum sativum leaf extract. Journal of Photochemistry and Photobiology B: Biology. 2016;**163**: 69-76

[72] Mittal AK et al. Comparative studies of anticancer and antimicrobial potential of bioinspired silver and silver-selenium nanoparticles. Journal of Materials NanoScience. 2016;**3**(2):22-27

[73] Venugopal K et al. Synthesis of silver nanoparticles (Ag NPs) for anticancer activities (MCF 7 breast and A549 lung cell lines) of the crude extract of Syzygium aromaticum. Journal of Photochemistry and Photobiology B: Biology. 2017;**167**:282-289

[74] Devaraj P et al. Synthesis and characterization of silver nanoparticles using Tabernae Montana divaricata and its cytotoxic activity against MCF7 cell line. International Journal of Pharmacy and Pharmaceutical Sciences. 2014;**6**(8): 86-90

[75] Kajani AA et al. Green synthesis of anisotropic silver nanoparticles with potent anticancer activity using Taxus baccata extract. RSC Advances. 2014; **4**(106):61394-61403

[76] Devi JS, Bhimba BV, Ratnam K. In vitro anticancer activity of silver nanoparticles synthesized using the extract of Gelidiella sp. International Journal of Pharmacy and Pharmaceutical Sciences. 2012;**4**(4):710-715

[77] Mishra A et al. Effect of biologically synthesized silver nanoparticles on human cancer cells. Science of Advanced Materials. 2012;**4**(12):1200-1206

[78] Sukirtha R et al. Cytotoxic effect of green synthesized silver nanoparticles using Melia azedarach against in vitro HeLa cell lines and lymphoma mice model. Process Biochemistry. 2012; **47**(2):273-279

[79] Shawkey AM et al. Green nanotechnology: Anticancer activity of silver nanoparticles using Citrullus colocynthis aqueous extracts. Advances in Life Science and Technology. 2013;**13**: 60-70

[80] Arunachalam KD et al. Potential anticancer properties of bioactive compounds of Gymnema sylvestre and its biofunctionalized silver nanoparticles. International Journal of Nanomedicine. 2015;**10**:31

[81] Kanipandian N, Li D, Kannan S. Induction of intrinsic apoptotic signaling pathway in A549 lung cancer cells using silver nanoparticles from Gossypium hirsutum and evaluation of in vivo toxicity. Biotechnology Reports. 2019;**23**: e00339

[82] Avalos A, Haza AI, Mateo D, Morales P. Interactions of manufactured silver nanoparticles of different sizes with normal human dermal fibroblasts. International Wound Journal. 2016; **13**(1):101-109

[83] Mei L, Xu Z, Shi Y, Lin C, Jiao S, Zhang L, et al. Multivalent and synergistic chitosan oligosaccharide-Ag nanocomposites for therapy of bacterial infection. Scientific Reports. 2020;**10**(1): 1-9

[84] Fani S, Kamalidehghan B, Lo KM, Nigjeh SE, Keong YS, Dehghan F, et al. Anticancer activity of a monobenzyltin complex C1 against MDA-MB-231 cells through induction of apoptosis and inhibition of breast cancer stem cells. Scientific Reports. 2016;**6**(1):1-15

[85] Verano-Braga T, Miethling-Graff R, Wojdyla K, Rogowska-Wrzesinska A, Brewer JR, Erdmann H, et al. Insights into the cellular response triggered by silver nanoparticles using quantitative proteomics. ACS Nano. 2014;**8**(3): 2161-2175

[86] Nadeem M, Khan R, Afridi K, Nadhman A, Ullah S, Faisal S, et al. Green synthesis of cerium oxide nanoparticles (CeO2 NPs) and their antimicrobial applications: A review. International Journal of Nanomedicine. 2020;**15**:5951

[87] Hembram KC, Kumar R, Kandha L, Parhi PK, Kundu CN, Bindhani BK. Therapeutic prospective of plant-induced silver nanoparticles: Application as antimicrobial and anticancer agent. Artificial Cells, Nanomedicine, and Biotechnology. 2018;**46**(supp. 3):S38-S51

[88] Yin IX, Zhang J, Zhao IS, Mei ML, Li Q, Chu CH. The antibacterial mechanism of silver nanoparticles and its application in dentistry. International Journal of Nanomedicine. 2020;**15**:2555

[89] Khatoon N, Alam H, Khan A, Raza K, Sardar M. Ampicillin silver nanoformulations against multidrug resistant bacteria. Scientific Reports. 2019;**9**(1):1-10

[90] Durán N, Durán M, De Jesus MB, Seabra AB, Fávaro WJ, Nakazato G. Silver nanoparticles: A new view on mechanistic aspects on antimicrobial activity. Nanomedicine: Nanotechnology, Biology and Medicine. 2016;**12**(3):789-799

[91] Du J, Tang J, Xu S, Ge J, Dong Y, Li H, et al. A review on silver nanoparticles-induced ecotoxicity and the underlying toxicity mechanisms. Regulatory Toxicology and Pharmacology. 2018;**98**:231-239

[92] Rasheed T, Bilal M, Iqbal HM, Li C. Green biosynthesis of silver nanoparticles using leaves extract of Artemisia vulgaris and their potential

biomedical applications. Colloids and Surfaces B: Biointerfaces. 2017;**158**: 408-415

[93] Baghani M, Es-haghi A. Characterization of silver nanoparticles biosynthesized using Amaranthus cruentus. Bioinspired, Biomimetic and Nanobiomaterials. 2020;**9**(3):129-136

[94] Keshari AK, Srivastava R, Singh P, Yadav VB, Nath G. Antioxidant and antibacterial activity of silver nanoparticles synthesized by Cestrum nocturnum. Journal of Ayurveda and Integrative Medicine. 2020;**11**(1):37-44

[95] Ahmad A, Wei Y, Syed F, Tahir K, Rehman AU, Khan A, et al. The effects of bacteria-nanoparticles interface on the antibacterial activity of green synthesized silver nanoparticles. Microbial Pathogenesis. 2017;**102**: 133-142

[96] Salayová A, Bedlovičová Z, Daneu N, Baláž M, Lukáčová Bujňáková Z, Balážová Ľ, et al. Green synthesis of silver nanoparticles with antibacterial activity using various medicinal plant extracts: Morphology and antibacterial efficacy. Nanomaterials. 2021;**11**(4):1005

[97] Awwad AM, Salem NM, Abdeen AO. Green synthesis of silver nanoparticles using carob leaf extract and its antibacterial activity. International Journal of Industrial Chemistry. 2013; **4**(1):1-6

[98] Bhakya S, Muthukrishnan S, Sukumaran M, Muthukumar M. Biogenic synthesis of silver nanoparticles and their antioxidant and antibacterial activity. Applied Nanoscience. 2016; **6**(5):755-766

[99] Ramteke C, Chakrabarti T, Sarangi BK, Pandey R-A. Synthesis of silver nanoparticles from the aqueous extract of leaves of Ocimum sanctum for enhanced antibacterial activity. Journal of Chemistry. 2013;**2013**

[100] Krishnaraj C, Jagan E, Rajasekar S, Selvakumar P, Kalaichelvan P, Mohan N. Synthesis of silver nanoparticles using Acalypha indica leaf extracts and its antibacterial activity against water borne pathogens. Colloids and Surfaces B: Biointerfaces. 2010;**76**(1):50-56

[101] Hungund BS, Dhulappanavar GR, Ayachit NH. Comparative evaluation of antibacterial activity of silver nanoparticles biosynthesized using fruit juices. Journal of Nanomedicine & Nanotechnology. 2015;**6**(2):1

[102] Velmurugan P, Anbalagan K, Manosathyadevan M, Lee K-J, Cho M, Lee S-M, et al. Green synthesis of silver and gold nanoparticles using Zingiber officinale root extract and antibacterial activity of silver nanoparticles against food pathogens. Bioprocess and Biosystems Engineering. 2014;**37**(10): 1935-1943

[103] Dhand V, Soumya L, Bharadwaj S, Chakra S, Bhatt D, Sreedhar B. Green synthesis of silver nanoparticles using Coffea arabica seed extract and its antibacterial activity. Materials Science and Engineering: C. 2016;**58**:36-43

[104] Salem W, Haridy M, Sayed W, Hassan N. Antibacterial activity of silver nanoparticles synthesized from latex and leaf extract of Ficus sycomorus. Industrial Crops and Products. 2014;**62**: 228-234

[105] Sheikholeslami S, Mousavi SE, Ashtiani HRA, Doust SRH, Rezayat SM. Antibacterial activity of silver nanoparticles and their combination with zataria multiflora essential oil and

methanol extract. Jundishapur Journal of Microbiology. 2016;**9**(10)

[106] Sk I, Khan MA, Haque A, Ghosh S, Roy D, Homechuadhuri S, et al. Synthesis of gold and silver nanoparticles using Malva verticillata leaves extract: Study of gold nanoparticles catalysed reduction of nitro-Schiff bases and antibacterial activities of silver nanoparticles. Current Research in Green and Sustainable Chemistry. 2020;**3**:100006

[107] Sun Q, Cai X, Li J, Zheng M, Chen Z, Yu C-P. Green synthesis of silver nanoparticles using tea leaf extract and evaluation of their stability and antibacterial activity. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2014;**444**:226-231

[108] Antony JJ, Sivalingam P, Siva D, Kamalakkannan S, Anbarasu K, Sukirtha R, et al. Comparative evaluation of antibacterial activity of silver nanoparticles synthesized using Rhizophora apiculata and glucose. Colloids and Surfaces B: Biointerfaces. 2011;**88**(1):134-140

[109] Lee J-H, Lim J-M, Velmurugan P, Park Y-J, Park Y-J, Bang K-S, et al. Photobiologic-mediated fabrication of silver nanoparticles with antibacterial activity. Journal of Photochemistry and Photobiology B: Biology. 2016;**7**(162): 93-99

[110] Murugan K, Senthilkumar B, Senbagam D, Al-Sohaibani S. Biosynthesis of silver nanoparticles using acacia leucophloea extract and their antibacterial activity. International Journal of Nanomedicine. 2014;**6**(9): 24-31

[111] Khalil MM, Ismail EH, El-Baghdady KZ, Mohamed D. Green synthesis of silver nanoparticles using olive leaf extract and its antibacterial activity. Arabian Journal of Chemistry. 2014;**7**(6): 1131-1139

[112] Kaman P, Dutta P, Bhattacharyya A. Synthesis of Gold Nanoparticles from Metarhizium Anisopliae for Management of Blast Disease of Rice and its Effect on Soil Biological Index and Physicochemical Properties. 2022. DOI: 10.21203/rs.3.rs-2080559/v1

[113] Ahmad A, Siddique JA, Laskar MA, Kumar R, Mohd-Setapar SH, Khatoon A, et al. New generation Amberlite XAD resin for the removal of metal ions: A review. Journal of Environmental Sciences. 2015;**31**:104-123

[114] Huang W, Wang C, Duan H, Bi Y, Wu D, Du J, et al. Synergistic antifungal effect of biosynthesized silver nanoparticles combined with fungicides. International Journal of Agriculture and Biology. 2018;**20**(5):1225-1229

[115] Akintelu SA, Olugbeko SC, Folorunso AS. Green synthesis, characterization, and antifungal activity of synthesized silver nanoparticles (AgNPS) from Garcinia Kola pulp extract. BioNanoScience. 2022;**12**(1): 105-115

[116] Rizwana H, Alzahrani T, Alwahibi MS, Aljowaie RM, Aldehaish HA, Alsaggabi NS, et al . Phytofabrication of silver nanoparticles and their potent antifungal activity against Phytopathogenic fungi. PRO. 2022;**10** (12):25-58

[117] Oliveira SS, Braga GC, Cordeiro NK, Stangarlin JR, Alves HJ. Green synthesis of silver nanoparticles with Euphorbia tirucalli extract and its protection against microbial decay of strawberries during storage. Journal of Food Science and Technology. 2022; **59**(5):2025-2034

[118] Purohit A, SR harma, RS hiv Ramakrishnan, S Sharma, A Kumar, et6al. Biogenic synthesis of silver nanoparticles (AgNPs) using aqueous leaf extract of Buchanania lanzan Spreng and evaluation of their antifungal activity against Phytopathogenic fungi. Bioinorganic Chemistry and Applications. 2022;**6**(44):5-8

[119] Vinodhini S, Vithiya BSM, Prasad TAA. Green synthesis of silver nanoparticles by employing the Allium fistulosum, Tabernaemontana divaricate and Basella alba leaf extracts for antimicrobial applications. Journal of King Saud University-Science. 2022; **34**(4):101939

[120] Malik MA, Batterjee MG, Kamli MR, Alzahrani KA, Danish EY, Nabi A. Polyphenol-capped biogenic synthesis of noble metallic silver nanoparticles for antifungal activity against Candida auri. Journal of Fungi. 2022;**8**(6):639

[121] Dutta T, Chowdhury SK, Ghosh NN, Chattopadhyay AP, Das M, Mandal V. Green synthesis of antimicrobial silver nanoparticles using fruit extract of Glycosmis pentaphylla and its theoretical explanations. Journal of Molecular Structure. 2022;**1247**: 131-361

[122] Ghetas HA, Abdel-Razek N, Shakweer MS, Abotaleb MM, Paray BA, Ali S, et al. Antimicrobial activity of chemically and biologically synthesized silver nanoparticles against some fish pathogens. Saudi Journal of Biological Sciences. 2022;**29**(3): 1298-1305

[123] Mishra S, Kumavat S. Green synthesis, characterization and antimicrobial activity of silver nanoparticles using Uraria picta leaves extract. Micro and Nanosystems. 2022; **14**(3):212-225

[124] Nallappan D et al. Green biosynthesis, antioxidant, antibacterial, and anticancer activities of silver nanoparticles of Luffa acutangula leaf extract. BioMed Research International. 2021

[125] Attallah NG, Elekhnawy E, Negm WA, Hussein IA, Mokhtar FA, Al-Fakhrany OM. In vivo and in vitro antimicrobial activity of biogenic silver nanoparticles against Staphylococcus aureus clinical isolates. Pharmaceuticals. 2022;**15**(2):194

[126] Khan M, Karuppiah P, Alkhathlan HZ, Kuniyil M, Khan M, Adil SF, et al. Green synthesis of silver nanoparticles using Juniperus procera extract: Their characterization, and biological activity. Crystals. 2022;**12**(3): 420

[127] Win TT, Khan S, Bo B, Zada S, Fu P. Green synthesis and characterization of Fe3O4 nanoparticles using chlorella-K01 extract for potential enhancement of plant growth stimulating and antifungal activity. Scientific Reports. 2021;**11**(1): 1-11

[128] Thanighaiarassu RR, Nambikkairaj B, Ramya DR. "Green synthesis of silver nanoparticles and characterization using plant leaf essential oil compound citral and their antifungal activity against human pathogenic fungi". Journal of Pharmacognosy and Phytochemistry. 2018;7(6):902-907

[129] Sanguiñedo P, Estevez MB, Faccio R, Alborés S. Biogenic silver nanoparticles from the fungus Punctularia atropurpurascens for the control of microorganisms. Mundo nano. Revista interdisciplinaria en

nanociencias y nanotecnología. 2019; **12**(22):10-20

[130] Elbahnasawy MA, Shehabeldine AM, Khattab AM, Amin BH, Hashem AH. Green biosynthesis of silver nanoparticles using novel endophytic Rothia endophytica: Characterization and anticandidal activity. Journal of Drug Delivery Science and Technology. 2021;**62**: 102-401

[131] Azarbani F, Shiravand S. Green synthesis of silver nanoparticles by Ferulago macrocarpa flowers extract and their antibacterial, antifungal and toxic effects. Green Chemistry Letters and Reviews. 2020;**13**(1):41-49

[132] Abdallah BM, Ali EM. Green synthesis of silver nanoparticles using the lotus lalambensis aqueous leaf extract and their anti-candidal activity against oral candidiasis. ACS Omega. 2021;**6**(12):8151-8162

[133] Mortezagholi B, Movahed E, Fathi A, Soleimani M, Forutan A, Mirhosseini NZ, et al. Plant-mediated synthesis of silver-doped zinc oxide nanoparticles and evaluation of their antimicrobial activity against bacteria cause tooth decay. Microscopy Research and Technique. 2022;**85**(11):3553-3564

[134] Lee WF, Huang YC. Swelling and antibacterial properties for the superabsorbent hydrogels containing silver nanoparticles. Journal of Applied Polymer Science. 2007;**106**(3):1992-1999

[135] Wild C, Weiderpass E, Stewart BW. World Cancer Report: Cancer Research for Cancer Prevention. International Agency for Research on Cancer. IARC Press; 2020

[136] Dziedzic A, Kubina R, Bułdak RJ, Skonieczna M, Cholewa K. Silver nanoparticles exhibit the dose-dependent anti-proliferative effect against human squamous carcinoma cells attenuated in the presence of berberine. Molecules. 2016;**21**(3):365

[137] Ahn E-Y, Jin H, Park Y. Assessing the antioxidant, cytotoxic, apoptotic and wound healing properties of silver nanoparticles green-synthesized by plant extracts. Materials Science and Engineering: C. 2019;**101**:204-216

[138] Gomathi A, Rajarathinam SX, Sadiq AM, Rajeshkumar S. Anticancer activity of silver nanoparticles synthesized using aqueous fruit shell extract of Tamarindus indica on MCF-7 human breast cancer cell line. Journal of Drug Delivery Science and Technology. 2020;**55**:101376

[139] He Y, Li X, Zheng Y, Wang Z, Ma Z, Yang Q, et al. A green approach for synthesizing silver nanoparticles, and their antibacterial and cytotoxic activities. New Journal of Chemistry. 2018;**42**(4):2882-2888