

BIOSYNTHESIS OF SILVER NANOPARTICLES FROM FUNGAL ROOT ENDOPHYTES OF *SIDA ACUTA* PLANT AND EVALUATION OF THEIR ANTIBACTERIAL AND ANTIBIOTIC ENHANCING ACTIVITY

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ABSTRACT

Objectives: Biosynthesis of silver nanoparticles has received much attention in recent years due to their numerous advantages over physical and chemical synthesis like being eco friendly, free from hazardous chemicals etc. Large number of biological agents are used for the biosynthesis of metal nanoparticles including plants and microbes. Amongst microbes fungi are better candidates for biosynthesis of various metal nanoparticles owing to certain physiological, morphological and metabolic characteristics. Further amongst fungi, the potential of endophytic fungi for the biosynthesis of metal nanoparticles has been less explored. Therefore, in present communication, the two important endophytic fungi isolated from *Sida acuta* (Wire weed) plant have been screened out for their potential to synthesize silver nanoparticles. The synthesized silver nanoparticles were further evaluated for antibacterial and antibiotic enhancing activity.

Methods: The fungal root endophytes isolated from *Sida acuta* plants were identified by studying morphological and microscopical characteristics and were keyed out to their respective genus by consulting relevant literature. The silver nanoparticle synthesizing potential of the isolated fungal endophytes was observed visually and confirmed by UV/Visible spectroscopical analysis under the wavelength range of 380-680 nm. These silver nanoparticles were further characterized by transmission electron microscopy (TEM), particle size analyzer (PSA) and Fourier transform infrared spectroscopy (FTIR) analysis. In addition, their antibacterial and antibiotic enhancing activities against four standard bacterial pathogens (*Escherichia coli*, MRSA, *Pseudomonas aeruginosa* and *Staphylococcus aureus*) were also evaluated as per the standard disk diffusion method.

Results: The two fungal root endophytes were isolated from *Sida acuta* plant and were identified as the species of *Syncephalis* and *Geotrichum*. Both these species were capable of synthesizing the silver nanoparticles as observed by the change in colour of the reaction mixture from transparent to dark brown and was confirmed by UV/Visible spectroscopy by observing the peaks of silver nanoparticles in the wavelength range of 380-680 nm. TEM analysis and study performed with particle size analyser revealed the silver nanoparticle synthesized by both the species varied in size and were mostly spherical in shape. While the FTIR analysis indicated the involvement of different functional groups in the silver nanoparticles synthesis by both the species. Besides, the synthesized silver nanoparticles was found to possess potential antimicrobial activity and was also capable of enhancing the efficiencies of some commercial antibiotics.

Conclusion: The fungal root endophytes, *Syncephalis* and *Geotrichum* isolated from plant *Sida acuta* were capable of synthesizing silver nanoparticles with remarkable antibacterial and antibiotic enhancing properties.

Keywords: *Sida acuta*, Silver nanoparticles, Endophytic fungi, TEM, PSA, FTIR, Antibacterial, Antibiotic enhancer.

INTRODUCTION

Nanotechnology is the technology by which we can manipulate the properties of matter at the nanoscale level. Properties of nanomaterials are different from their bulk counterparts as a result of which they can be used in many industries [1]. These can be synthesized by number of ways including physical, chemical and biological methods [2]. In the recent years biological method has gained much attention due to certain properties like being an eco friendly way of synthesis, free from hazardous chemicals etc. Among biological methods, much of the work has been done on plants, plant products, extracts etc. However, microorganisms like bacteria and fungi particularly the endophytic fungi have been explored very less despite having equal potential to synthesize various metal nanoparticles [3]. Endophytes can be defined as the microbes which reside inside the plant tissues asymptotically without being pathogenic to the host [4]. These endophytes produce certain compounds either intracellularly or extracellularly which causes reduction of silver nitrate to silver nanoparticles [5]. Therefore, in the present investigation an attempt has been made to biosynthesize the silver nanoparticles using two important endophytic fungal organisms isolated from the roots of *Sida acuta* plant.

MATERIALS AND METHODS

Isolation and identification of fungal root endophytes

The sample of *Sida acuta* plant for isolation of fungal root endophytes was obtained from medicinal garden of Panjab

University, Chandigarh, India. The isolation of fungal endophyte/s from root of the plant was made as per Hallman *et al* [6]. In this method the root samples of *Sida acuta* plant were first washed under running tap water to remove any dust or debris attached to it. After that the samples were immersed in 70% ethanol for 1 minute and then in sodium hypochloride solution (4%) (v/v) for 4 minutes. Samples were again rinsed with 70% ethanol for 1 minute and finally rinsed with sterilized distilled water to remove the sterilants used and blot dried on sterile blotting paper. The sterilized root samples were cut into small pieces (about 1-2 cm) by sterilized scalpel and inoculated in Petri plates containing potato dextrose agar medium (PDA) supplemented with chloramphenicol. A control was also maintained in the same plate to observe the appearance of probable epiphytes. This was done by making the imprints of root parts parallel to the 'test inoculation' on the agar surface. The absence of any epiphytic growth in the imprint region indicated that the sterilization method was effective. The plates were then incubated at 28±0.5°C and monitored every day for the appearance of endophytic fungal growth. The successfully isolated fungal root endophytes was numbered as SRE7 and SRE8 and were identified as per Tieghem & Le Monnier [7] and Kurtzman & Fell [8] respectively on the basis of studies made on morphological and microscopical characteristics and by consulting relevant literature.

Biosynthesis of silver nanoparticles

The biosynthesis of silver nanoparticle was done as per method of Hemanth *et al* [9]. In this method, the required fungal biomass was

cultivated by growing the fungal root endophytes in 250 ml flask containing 100 ml of potato dextrose broth (PDB) separately, incubated at 28±0.5°C for 7 days under shaking. After incubation, the fungal biomass was harvested either by filtration or centrifugation (at 10,000 rpm for 10 minutes). The pellets of fungal biomass so obtained were washed 3-4 times with water to remove any attached media components. 10 gm of this mycelial biomass was suspended in 100 ml sterilized water in 250 ml flask, incubated at 28±0.5°C, for 3 days under shaking. After that, the mycelial biomass was separated from the water by filtering and the cell filtrate was used further for the biosynthesis of silver nanoparticles.

The reduction reaction for biosynthesis of silver nanoparticle was carried by adding 0.5 ml of 0.1M silver nitrate in 49.5 ml of cell filtrate so as to get the 1 mM volume as the final concentration of silver nitrate in the reaction mixture. A control containing cell filtrate without silver nitrate was also maintained under the same conditions. The formation of silver nanoparticles was monitored visually by observing the change of colour in the reaction mixture (i. e., colour change from colourless/yellow to dark brown) and also by UV/Visible spectrophotometry under the wavelength scan of 200-800 nm.

Characterization of silver nanoparticles

The characterization of size, shape and dispersity of mycosynthesized silver nanoparticles was done by analyzing the nanoparticles by transmission electron microscopy (TEM) and particle size analyzer (PSA). The presence of various functional groups was analyzed by fourier transform infrared spectroscopy (FTIR).

Evaluation of antibacterial activity of silver nanoparticles

Antibacterial activity of biosynthesized silver nanoparticles was studied as per agar diffusion method of Midolo *et al* [10]. The antibacterial activity was evaluated against standard bacterial pathogens, *Escherichia coli*, *Methicillin resistant Staphylococcus aureus* (MRSA), *Pseudomonas aeruginosa* and *Staphylococcus aureus*. In this method, the test bacterial pathogens were first inoculated on nutrient agar by the spread plate method. The wells were made by sterile borer on the nutrient agar plates and loaded with 15 µl of silver nanoparticles under aseptic conditions and incubated for 24 hrs at 37°C. The formation of zone of inhibition (if any) was observed after 24 hrs and expressed in millimeters (mm). The percentage inhibition was also calculated using the formula:

$$\text{Percentage Inhibition (\%)} = \frac{t - c}{c} \times 100$$

where, 't' = zone of inhibition obtained by placing disc coated with silver nanoparticles and

'c' = zone of inhibition obtained by placing disc coated with silver nitrate solution.

Evaluation of antibiotic enhancing activity of silver nanoparticles

Antibacterial enhancing activity of biosynthesized silver nanoparticles in combination with some important commercial antibiotics was also evaluated as per disk diffusion method of Bauer *et al* [11]. In this method, the standard antibiotic discs (Penicillin, Methicillin, Ampicillin and Amoxicillin) with concentration 10µg each were impregnated with biosynthesized silver nanoparticles (10 µl) and placed on nutrient agar plate pre-inoculated with bacterial test pathogens (*Escherichia coli*, MRSA, *Pseudomonas aeruginosa* and *Staphylococcus aureus*) and incubated at 37°C for 24 hrs. The formation of zone of inhibition (if any) was observed and measured in millimeters and compared with control i. e., disc with silver nitrate only and antibiotic discs without silver nanoparticles. The increase in fold area was assessed as per Birla *et al* [12] by calculating the mean surface area of the zone of inhibition of each antibiotic (A) and antibiotic + silver nanoparticle (B) using the formula (B²-A²)/A² where 'A' and 'B' were zones of inhibition for antibiotic and antibiotic + silver nanoparticles respectively. In case of absence of zone of inhibition of '[A]', the standard diameter of antibiotic disc itself (6 mm) was considered as the zone as per Birla *et al* [12].

RESULTS AND DISCUSSION

Isolation and identification of fungal root endophytes

The endophytic fungal cultures which were isolated from the root samples of the plant *Sida acuta* were identified as the species of *Syncephalis* and *Geotrichum* by studying various morphological and microscopical characteristics and consulting relevant literature (Table 1-2; Fig. 1).

Biosynthesis of silver nanoparticles

The biosynthesis of silver nanoparticles by the endophytic fungi was evaluated visually by observing the change of colour of reaction mixture from transparent/yellowish to dark-brown which was due to the reduction of silver ions to silver nanoparticles (i. e., Ag⁺ to Ag⁰) (Figure 2). The biosynthesis of silver nanoparticles was also assessed by UV/Visible spectroscopical analysis of the reaction mixture by observing peak of the biosynthesized silver nanoparticles in the range of 380-680 nm which is the defined range of the silver nanoparticles (Figure 3-4). It was observed that with increase in time, there was increase in absorption peak which ultimately showed the increase in concentration of silver nanoparticles with time. Biosynthesis of silver nanoparticles was indicated by the peaks obtained in 380-680 nm due to surface plasmon resonance.

Table 1: Morphological and microscopical characteristics of *Syncephalis* species isolated from roots of *Sida acuta* plant.

Morphological characteristics				
Colony	Size	Shape	Texture	Colour
On PDA: diffused	Up to 2 cm in diameter	Irregular, radial, flat; margin entire	Rough, dry	Grayish black at the centre, yellowish periphery, turning grey at maturity
Microscopic characteristics				
Merospores	Merosporangia	Sporophores	Hyphae	
Present as doliiform shaped	Present on sporophores emerges as papillae which gradually elongated to form long, thin cylindrical outgrowths (30.0-36.0 µm).	Simple, undivided, radiating from the head of the mature sporophores	Hyaline, double walled	

Table 2: Morphological and microscopical characteristics of *Geotrichum* species isolated from roots of *Sida acuta* plant.

Morphological characteristics				
Colony	Size	Shape	Texture	Colour
On PDA plate, aggregated.	2-3 cm in diameter	Irregular, slightly elevated at the centre	Rough, dry, margin entire	White to cream coloured
Microscopic characteristics				
Arthroconidia		Hyphae		
7.2-10.0 x 3.0-5.5 µm, unicellular, in chains, hyaline, usually rounded, few rectangular		Fragmented hyphae obtained from undifferentiated hyphae by fission of the filament. Abundant true mycelium observed, 4.0-6.5 µm wide		



Fig. 1: A) The host *Sida acuta* plant; B) Pure culture of endophytic *Syncephalis* sp. isolated from the roots of *Sida acuta* plant; C): Microscopic fructification of *Syncephalis* sp.; D): Culture of endophytic *Geotrichum* sp. isolated from the roots of *Sida acuta* plant; E): Microscopic image of *Geotrichum* sp.

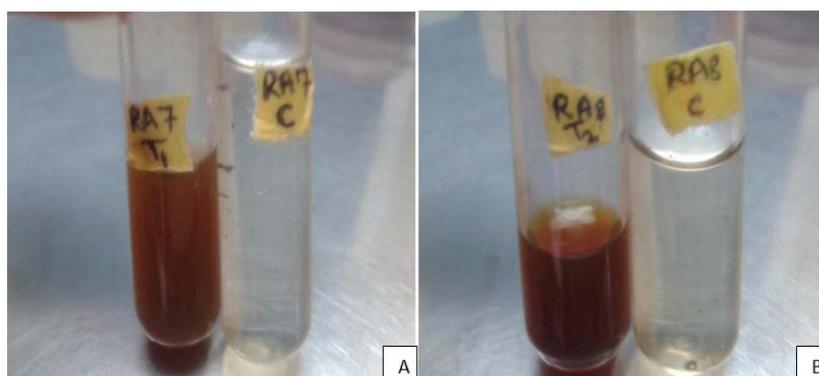


Fig. 2: Change in colour of reaction mixture from transparent (control) (C) to brown (Test) (T), indicating the biosynthesis of silver nanoparticles on 5th(144 hrs) of incubation by (A) *Syncephalis* sp. and (B) *Geotrichum* sp.

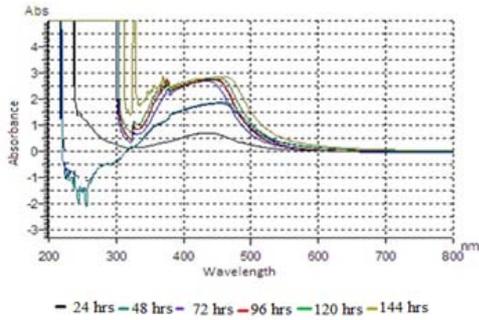


Fig. 3: Peaks of silver nanoparticles synthesized by *Syncephalis* sp. after 24, 48, 72, 96, 120 and 144 hrs obtained by UV/Visible spectroscopic analysis.

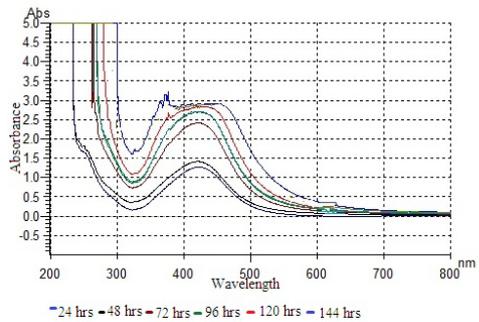


Fig. 4: Peaks of silver nanoparticle synthesized by *Geotrichum* sp. after 24, 48, 72, 96, 120 and 144 hrs obtained by UV/Visible spectroscopic analysis.

Characterization of silver nanoparticles by TEM

The characterization of biosynthesized silver nanoparticles by TEM revealed the polydisperse nature of the nanoparticles. Nanoparticles synthesized by *Syncephalis* sp. varied in size from 6.40 nm to 16.9 nm (Figure 5) where as the nanoparticles of *Geotrichum* sp. were found in the range of 3.63 nm to 14.2 nm (Figure 6). However, in both the cases shape was found to be mostly spherical.

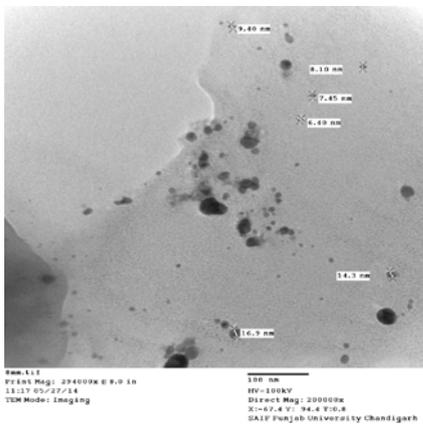


Fig. 5: TEM of silver nanoparticles synthesized by *Syncephalis* sp. showing variable size range.

Characterization of silver nanoparticles by FTIR

FTIR analysis of the silver nanoparticles gives us information about the chemical bonds and molecular structures of possible compounds that could play an important role in the formation and stability of nanoparticles [13]. Peak obtained in the FTIR spectra of

nanoparticles by *Syncephalis* sp. (Figure 7) at 1650 cm^{-1} is due to C=O stretch vibrations and at 1436 cm^{-1} due to N-H stretch vibrations while their corresponding stretching vibrations were seen around 3300 and 2900 cm^{-1} respectively. Peak around 1047 cm^{-1} can be assigned to the C-N stretching vibrations of the aliphatic amines (Figure 7).

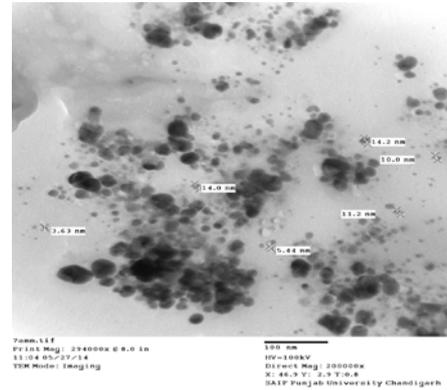


Fig. 6: TEM of silver nanoparticles synthesized by root endophytic *Geotrichum* sp. showing variable size range.

Peak obtained in the FTIR spectra of nanoparticles by *Geotrichum* sp. (Figure 8) at 1646 and 1437 cm^{-1} it is due to stretch vibrations of -C=O and N-H groups respectively. Peak around 2900 cm^{-1} can be assigned to the stretching vibrations of secondary amines. While peaks in the region of 3400 cm^{-1} can be assigned to O-H stretching of alcohol This indicated the involvement of different compounds and functional groups in silver nanoparticle biosynthesis.

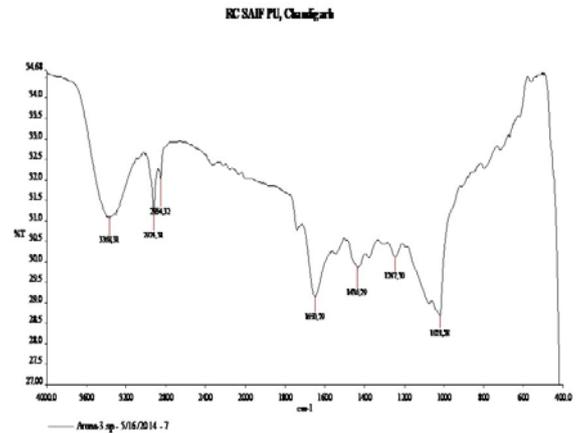


Fig. 7: FTIR of silver nanoparticles synthesized by root endophytic species of *Syncephalis*.

Characterization of silver nanoparticles by Particle Size Analyser (PSA)

Particle size analysis of silver nanoparticles was performed using Malvern Hydro 2000S particle size analyzer. The principle of particle size analyzer is that when a focused laser beam is passed through the particle preparation, the particles scatter the light at angles inversely proportional to their size. The map of scattering intensity versus angle is the primary source of information used to calculate the particle size. The result obtained revealed that 10% particles of the total population of nanoparticles biosynthesized by both the species i. e., *Geotrichum* and *Syncephalis* were less than 72 nm (i. e. $d(0.1)=72$ nm). The median size of the nanoparticle population was found to be 92 nm for *Syncephalis* 88 nm for *Geotrichum* species. Variation in the size of the nanoparticles synthesized by both the species is clearly displayed in figure 9 and 10. This was also revealed

by TEM analysis. Thus, the present fungal isolates have the potential to biosynthesize silver nanoparticles of a varying size range which may find multifarious applications in medical field.

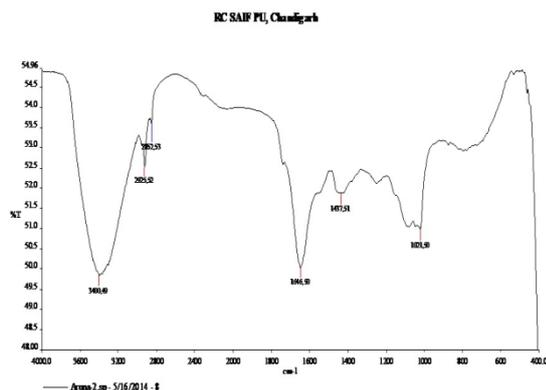


Fig. 8: FTIR of silver nanoparticles synthesized by root endophytic species of *Geotrichum*.

Antibacterial activity of biosynthesized silver nanoparticles

The antibacterial activity of the biosynthesized silver nanoparticles was determined by agar diffusion method. It was measured as the size (diameter) of the zone of inhibition in mm and their percentage inhibition was also calculated (Table 3). The bigger the zone of inhibition, the higher the antibacterial activity. The result obtained revealed that the silver nanoparticles were quite effective in inhibiting the growth more or less of all the test bacterial strains. However, the maximum inhibitory activity of silver nanoparticles produced by *Syncephalis* species was found against *Staphylococcus aureus* (50%) while in case of *Geotrichum* species it was found against *Escherichia coli* (80%) (Figure 11).

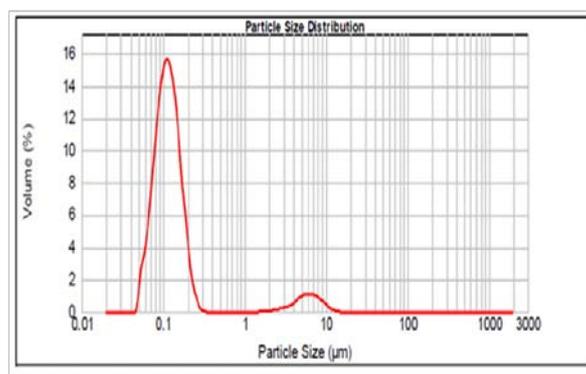


Fig. 9: Particle size analysis of silver nanoparticles synthesized by root endophytic species of *Syncephalis*

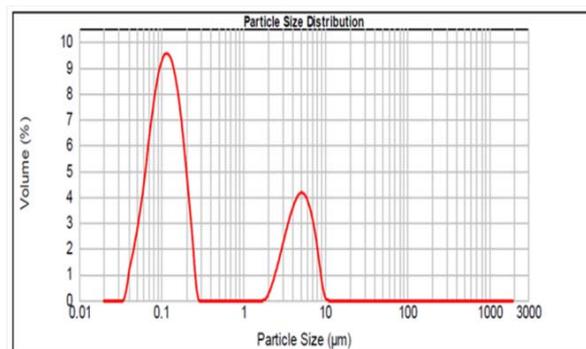


Fig. 10: Particle size analysis of silver nanoparticles synthesized by root endophytic species of *Geotrichum*.

Table 3: Zone of inhibition obtained by silver nanoparticles produced by endophytic fungal isolates against standard test bacterial strains.

Zone of inhibition by silver nanoparticles produced by <i>Syncephalis</i> sp.				
Test bacterial strains				
Zone of inhibition (in mm)	<i>Escherichia coli</i>	<i>Pseudomonas aeruginosa</i>	MRSA	<i>Staphylococcus aureus</i>
Control	10 mm	10 mm	10 mm	8 mm
Test	14 mm	13 mm	14 mm	12 mm
Percentage inhibition (%)	40	30	40	50
Zone of inhibition by silver nanoparticles produced by <i>Geotrichum</i> sp.				
Test bacterial strains				<i>Staphylococcus aureus</i>
Zone of inhibition (in mm)	<i>Escherichia coli</i>	<i>Pseudomonas aeruginosa</i>	MRSA	
Control	10 mm	10 mm	10 mm	8 mm
Test	18 mm	12 mm	16 mm	12 mm
Percentage inhibition (%)	80	20	60	50

Values are mean SD of three observations

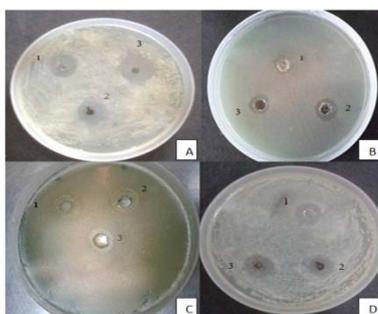


Fig. 11: Antibacterial activity of silver nanoparticles (1) Silver nitrate (Control); Silver nanoparticles produced by (2) *Syncephalis* sp. and (3) *Geotrichum* sp. against test bacteria: (A) MRSA; (B) *Staphylococcus aureus*; (C) *Pseudomonas aeruginosa*; (D) *Escherichia coli*.

Antibacterial enhancing activity of silver nanoparticles in combination with antibiotics

Biosynthesized silver nanoparticles were also evaluated for their ability to enhance the antibacterial activity of some important commercial antibiotics. For this penicillin, methicillin, amoxicillin and ampicillin were used as test antibiotics. The antibacterial enhancing activity was measured as increase in fold area of inhibitory zone.

The result obtained on the efficacy of silver nanoparticles (synthesized by *Syncephalis* sp. and *Geotrichum* sp.) in combination with antibiotics revealed an overall increase in fold area of zone of inhibition which indicated the increase in antibacterial potential of all the antibiotics against the test bacterial strains (Figure 12 & 13). It was also observed that there was no zone of inhibition in the control region i. e., antibiotics alone and silver nitrate in case of *Escherichia coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*.

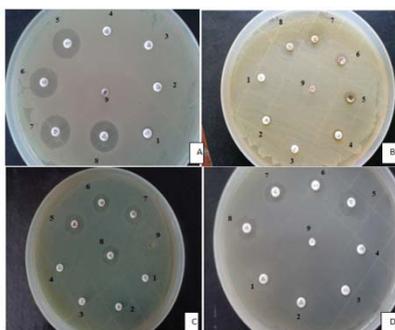


Fig. 12: Antibacterial activity of silver nanoparticles produced by fungal root endophytic isolate *Syncephalis* sp. in combination with commercial antibiotics.

[A] Activity against *Escherichia coli*; 1:P; 2: Met; 3: Amc; 4: Amp; 5: P+ SNPs; 6: Met+SNPs; 7: Amc+SNPs; 8: Amp+SNPs; 9: Silver nitrate control.[B] Activity against MRSA; 1:Amp; 2: Amc; 3: P; 4: Met; 5: Amp+ SNPs; 6: Amc+SNPs; 7: Met+SNPs; 8: P+SNPs; 9: Silver nitrate control.[C] Activity against *Pseudomonas aeruginosa*; 1:Met; 2: Amc; 3: P; 4: Amp; 5: P+ SNPs; 6: Amc+SNPs; 7: Met+SNPs; 8: Amp+SNPs; 9: Silver nitrate control.[D] Activity against *Staphylococcus aureus*; 1:Amp; 2: Amc; 3: Met; 4: P; 5: P+ SNPs; 6: Met+SNPs; 7: Amc+SNPs; 8: Amp+SNPs; 9: Silver nitrate control

However, the maximum increase in fold area of inhibition (13.6 fold increase) was obtained against *Escherichia coli* when methicillin was combined with the silver nanoparticle produced by *Syncephalis* sp. (Table 4).While in case of *Geotrichum* sp. the maximum increase in fold area was obtained against *Escherichia coli* when methicillin and amoxicillin were combined with silver nanoparticles (Table 5).

Table 4: Antibacterial activity of antibiotic alone and antibiotic in combination with silver nanoparticles synthesized by *Syncephalis* sp.

Test bacterial strain	<i>Escherichia coli</i>			MRSA			<i>Pseudomonas aeruginosa</i>			<i>Staphylococcus aureus</i>		
	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2 / [A]^2$	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2 / [A]^2$	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2 / [A]^2$	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2 / [A]^2$
Penicillin	-	22 mm	12.44	-	20mm	10.1	-	18 mm	8	-	16 mm	6.1
Methicillin	-	23 mm	13.6	8 mm	19 mm	4.64	-	15 mm	5.25	-	10 mm	1.7
Amoxicillin	-	22 mm	12.4	5 mm	10 mm	3	-	16 mm	6.1	-	12 mm	3
Ampicillin	-	24 mm	15	-	9 mm	1.25	-	16 mm	6.1	-	12 mm	3

Values are mean SD of three observations.

Ab: Antibiotic; Ab + AgNp: Antibiotic in combination with silver nanoparticle, Where [A] and [B] denotes Ab alone and Ab+ silver nanoparticle produced respectively and the increase in fold area of inhibition is shown by $[B]^2-[A]^2/[A]^2$.

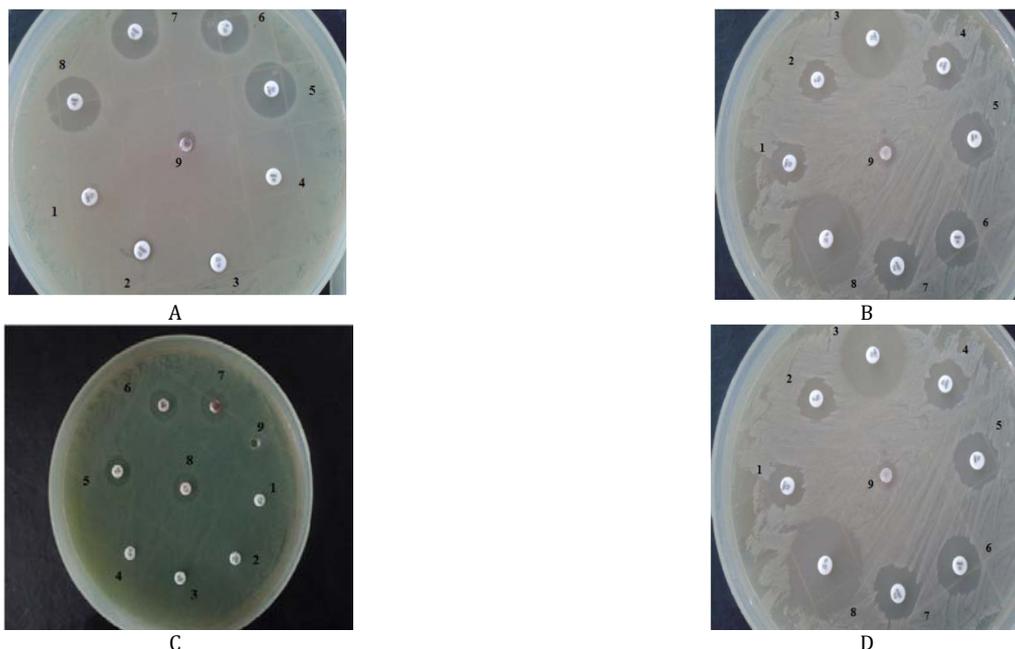


Fig. 13: Antibacterial activity of silver nanoparticles produced by fungal root endophytic isolate *Geotrichum* sp. in combination with commercial antibiotics.

[A] Activity against *Escherichia coli*; 1: Met; 2: Amp; 3: P; 4: Amc; 5: Met+ SNPs; 6: P+SNPs; 7: Amp+SNPs; 8: Amc+SNPs; 9: Silver nitrate control.[B] Activity against MRSA; 1:Met; 2: P; 3:Met+SNPs; 4: Amp; 5: Amc; 6: Amc+SNPs; 7: Amp+SNPs; 8: P+SNPs; 9: Silver nitrate control.[C] Activity against *Pseudomonas aeruginosa*; 1:Met; 2: Amp; 3: Amc; 4: P; 5: Amc+ SNPs; 6: Amp+SNPs; 7: Met+SNPs; 8: P+SNPs; 9: Silver nitrate control.[D] Activity against *Staphylococcus aureus*; 1:Met; 2: P; 3: Amc; 4: Amp; 5: Amc+ SNPs; 6: Amp+SNPs; 7: P+SNPs; 8: Met+SNPs; 9: Silver nitrate control.

Table 5: Antibacterial activity of antibiotic alone and antibiotic in combination with silver nanoparticles synthesized by *Geotrichum* sp.

Test bacterial strain	<i>Escherichia coli</i>			MRSA			<i>Pseudomonas aeruginosa</i>			<i>Staphylococcus aureus</i>		
	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2/[A]^2$	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2/[A]^2$	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2/[A]^2$	Ab [A]	Ab+ AgNp [B]	$[B]^2-[A]^2/[A]^2$
Penicillin	-	21 mm	11.25	22 mm	24 mm	0.19	-	14 mm	4.4	-	8 mm	0.7
Methicillin	-	23 mm	13.69	22 mm	35 mm	1.53	-	15 mm	5.25	-	18 mm	8
Amoxicillin	-	23 mm	13.69	21 mm	25 mm	0.41	-	15 mm	5.25	-	12 mm	3
Ampicillin	-	22 mm	12.4	22 mm	26 mm	0.39	-	16 mm	6.1	-	10 mm	1.7

Values are mean SD of three observations, Ab: Antibiotic; Ab + AgNp: Antibiotic in combination with silver nanoparticle, Where [A] and [B] denotes Ab alone and Ab+ silver nanoparticle produced respectively and the increase in fold area of inhibition is shown by, $[B]^2-[A]^2/[A]^2$.

CONCLUSION

Nanotechnology is a rapidly growing field with its applications in science and technology for the purpose of manufacturing new materials at the nanoscale level. By the use of nanotechnology we can manipulate the properties of nanomaterials according to our requirements. Nanoparticles can be synthesized by chemical and physical methods but due to certain disadvantages like being expensive and release of hazardous compounds, there is a need for alternative safer, efficient and economic methods. In this regard, the green technology of nanoparticle synthesis is the most preferred method now a days. Among biological means of nanoparticles synthesis, the fungi have got certain advantages by virtue of their physiological and morphological characteristics which have made the process of nanoparticle biosynthesis inexpensive and eco-friendly. Therefore, there is a need to screen out fungal isolates from diverse biotopes for their nanoparticles synthesizing capabilities which in turn may prove beneficial for various applications including medical as well as industrial.

CONFLICT OF INTERESTS

Declared none.

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