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Full Length Research Paper

Antimicrobial screening of different extracts of South Indian medicinal plants of meliaceae

Mukesh Sharma[1]*, Vimal Mohan[1], Maneesha Abraham[2], P. J. Joshy[2] and Drishya K. Reghuvaran[2]

[1]Microbiology Laboratory, Department of Botany, University of Rajasthan, Jaipur, Rajasthan, India.
[2]Department of Botany, DevaMatha College, Kottayam, Kerala, India.

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Members of Meliaceae are widely used by different tribal communities in South India for the treatment of many bacterial and fungal diseases. In this context, antimicrobial potential of aqueous and alcoholic soxhlet extracts of leaf, stem/bark and root of *Azadirachta indica*, *Naregamia alata* and *Swietenia mahagoni* against five bacterial strains was studied to validate the ethno therapeutic claims of these plants against different bacterial diseases. The alcoholic and aqueous extracts of the plants showed significant antibacterial activity against all the organisms: *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa Proteus vulgaris* and *Bacillus subtilis*. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) (mg/ml) of the alcoholic and aqueous extracts were also determined. The antibacterial potential of the plants were then compared with Benzyl Penicillin and Amphicillin, two common antibiotics employed in allopathic treatment of bacterial diseases. The alcoholic extracts of plants proved to be more effective than the aqueous extracts due to broad spectrum antibiotic compounds. The good antibacterial potency of the plants indicates the presence of some active principle in the phytoextracts, which can be purified and employed in the treatment of bacterial diseases as an alternative to the costly antibiotics.

Key words: Antibacterial activity, antibiotics, minimum inhibitory concentration, minimum bactericidal concentration, soxhlet extracts.

INTRODUCTION

The past few decades of modern medicines certainly helped man in controlling and even eliminating some of the deadly diseases, but at the same time, it paved the way for the formation of more and more antibiotic resistant pathogens (Hart et al.., 1998). This has increased the need for the development of novel antibiotics (Chopra et al., 1997). The use of plant extracts for their antimicrobial action has been the subject of research by many workers and many works have been carried out in this field recently, to discover new antimicrobial drugs of plant origin (Sofowora, 1984; Valsaraj et al., 1996; Sardari et al., 1998; Hamsaveni et al., 1999; Werner et al., 1999; Kudi et al., 1999; Perumalasamy et al., 1999; Perumalasamy and Ignachimuthu, 2000; Oudhia, 2001; Mohan et al., 2005a; Mohan et al., 2005b). *Azadirachta indica*, *Naregamia alata* and *Swietenia mahagoni* belongs to the family Meliaceae, distributed throughout South India. *N. alata* is a small handsome underground shrub up to 30 cm in height with pungent aromatic root and trifoliate leaf with winged petioles. The whole parts of *N. alata* are medicinally important. They are mainly used in the treatment of vitiated conditions of pitta, vata, cough, anemia, halitosis, asthma, bronchitis, splenomegaly scabies, pruritus, dysentery, dyspepsia, chronic and malarial fevers. The plant is acrid, sweet, cooling, aromatic, alexeteric, vulnenary, emetic cholagogue,

*Corresponding author. E-mail: mukeshsharma_uniraj@yahoo.co.in

expectorant, depurative and antipyretic. *A. indica* is an evergreen tree grows throughout India. It is used as vermifuge, insecticide, astringent, tonic and antiseptic. It possesses anti diabetic, anti bacterial and anti viral properties and used successfully in cases of stomach, worms and ulcers. Root barks posseses astringent properties. It is also useful in treatment of malarial fever. *S. mahagoni* is an evergreen to semi-evergreen tree of the family Meliaceace. Seeds are used for treatment of malaria, diabetes, cold, rheumatism, anorexia, eczema, blood pressure and scable. Bark serves as antipyretic, tonic and astringent. A human immunodeficiency virus protease inhibitory substance is reported from *S. mahagoni* (Matsuse et al., 1998). This plant species has ethno medical uses (Goun et al., 2003) and *in vitro* antibacterial and antifungal property of its extract has been reported (Goun et al., 2003).

The bacterial strains used were those commonly employed in microbiological studies. *Staphylococcus aureus* capable of causing food poisoning can cause infections like pioderma, impetigo ritter's disease, folliculities, furunculosis, staphylocoagulase carbuncle and sycosis barbar. It can also infect all kinds of wounds. *Pseudomonas aeruginosa* is also capable of infecting any wound, but are commonly associated with abdominal, urological and gynecological wounds. Both *S. aureus* and *P. aeruginosa* can cause pahophthalmitis of eye (Chakraborty, 1995 and Ronald, 1986). *Proteus vulgaris* is capable of infecting the urinary tract and wounds.

The antibacterial potential of *A. indica*, *N. alata* and *S. mahagoni* against different bacterial strains was studied. The study includes aqueous and alcoholic soxhlet extracts of leaf, stem/bark and root of the plants against five bacterial strains. The minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), dosage of old extracts against each bacterium was also evaluated and calculated.

MATERIALS AND METHODS

Plant materials

The fresh plant materials namely *A. indica*, syn. *Melia azadirachta* L., *N. alata* Wight and Arn., *S. mahagoni* (L.) Jacq. were collected from Kuravilangad, 10 km from Kottayam, Kerala, India. The plants were identified and the specimens have been deposited in the herbarium of Deva Matha College, Kuravialangad for future reference.

Extraction of plant materials

The healthy plant parts were collected dried under shade and ground into fine powder using electric blender. About 30 gm of dried powdered leaf, stem and root were soaked separately with 220 ml of hot water and ethanol in a soxhlet apparatus for 48 h.

Then, each mixture was refluxed followed by agitation at 200 rpm for 1 h. The extracts were evaporated to dryness and solutions of 5, 10, 15, 20 and 25% were prepared in the solvent in which it was extracted.

Bacterial strains and culture maintenance

The test microorganisms used for the antimicrobial screening viz. *S. aureus* (MTCC 737), *Escherichia coli* (MTCC 443), *P. aeruginosa* (MTCC 741), *P. vulgaris* (MTCC 426) and *Bacillus subtilis* (MTCC 441) were obtained from MTCC and Gene bank, IMTECH, Chandigarh, India. All the bacterial strains were maintained in Nutrient Agar medium (NA) (Hi-media, Bombay, India).

Inoculum

The microorganisms were inoculated into Nutrient Agar (NA) and incubated at 35 ± 2°C for 4 h. The turbidity of the resulting suspensions was diluted with nutrient broth to obtain a transmittance of 25.0% at 580 nm. This level of turbidity is equivalent to approximately 3.0×10^8 CFU/ml.

Determination of antibacterial assay

Filter paper disc diffusion method (Karaman et al., 2003) was used to study the effect of plant extracts on bacteria. Agar plates were prepared using NA obtained from Himedia (Mumbai). The plates, when half set were inoculated with bacteria using sterile cotton swabs, four sterile paper discs (6 mm diameter) of Whatman no. 1 filter paper, one dipped in pure solvent (as control) and three loaded with same concentration of plant extracts were placed above the inoculated plates. The three other discs of plant extracts as the experiment, gives three readings (triplicate) for inhibition zone. The mean value was taken, all the above procedure was done in aseptic conditions provided by a laminar airflow chamber. The plates were incubated at 37°C for 24 h in an incubator. The inhibition zone formed due to the allelopathic effect of the extracts was measured in millimeters. The mean of the three values from each plate was taken as the zone of inhibition. The above procedure was repeated for different concentration of leaf, stem and root extracts of all the three plants studied. The obtained zone of inhibition for the plant extracts was then compared with 25% antibiotics.

Determination of minimum inhibitory concentration and minimum bactericidal concentration

The MIC was evaluated on plant extracts that showed antimicrobial activity. MIC values were studied for microorganisms, which were determined by microdilution broth methods (Bassole et al., 2003). The broth medium containing 0.5 - 10 mg/ml dilution of plant extracts inoculated with bacterial strains. MIC was defined as the lowest concentration of the extract that inhibited visible growth on the medium. MBC was determined by subculturing the test dilution on to a fresh drug-free solid medium and incubating further for 18 - 24 h. The highest dilution that yielded no single bacterial colony on a solid medium was taken as MBC.

Statistical analysis

Results given in the table are mean ± standard error (S.E.). The data collected was analyzed using one-way analysis of variance. The effects were considered significant when P value of ANOVA F-test was < 0.05.

RESULTS

Filter paper disc diffusion method was used to determine

the zone of inhibition of the aqueous and ethanolic phytoextracts. The plants showed significant antibacterial activity against all the bacterial strains. Among the leaf extracts, *N. alata* leaf extract showed greater inhibition towards all the bacterial strains. The ethanolic extracts were found to be more effective than aqueous extracts (Table 1). Among the different stem/bark extracts of the plants studied aqueous extracts of *N. alata* stem showed maximum activity against *E. coli*, *P. vulgaris*, *P. aeruginosa* and *S. aureus*. The ethanolic extract of *A. indica* was found to be most effective against *B. subtilis* (Table 2). *N. alata* root extracts in ethanol and aqueous stem extracts, showed maximum activity against all the bacterial strains. The aqueous root extract of *S. mahagoni* failed to inhibit the growth of *E. coli* (Table 3). MIC and MBC values of the aqueous and ethanolic extracts of the plant parts are summarized in Tables 4a-c. The MIC values of ethanolic extracts were lower than that of aqueous extracts against all the bacterial strains. Inhibitory effect of phytoextracts on bacteria was compared with antibiotics such as benzyl penicillin and Amphicillin at 25% concentration. (Figure 1).The 25% stem extracts in ethanol showed a greater inhibition towards *E. coli* and *S. aureus* when compared with antibiotics.

DISCUSSION

The medicinal value of plants lies in some chemical substances that produce a definite physiological action on the human body. The most important of these bioactive compounds of plants are alkaloids, flavanoids, tannins and phenolic compounds (Edeoga et al., 2005). Majid et al. (2004) conducted antimicrobial activity and toxicity analysis of *S. mahagoni* seed oil. The refined oil was found to show good moderate activity against disease causing bacteria namely *Shigella dysenterial, Salmonella typhi, S. aureus* and fungal pathogens namely *Macrophomina phascolma, Alternaria alternata, Curvularia lunat*a. Govindachari et al. (1999) tested seven limonoids from *S. mahogani* for antifungal activity against the groundnut rust *Puccinia arachidi* and reported that, 6-acetylswietenine and 6-acetyl-3-tigloylswietenolide effectively reduced the number of rust pustules on detached groundnut leaves. In the present study the aqueous and alcoholic extracts of *S. mahagoni* showed significant antibacterial efficiency against almost all the bacterial strains. The aqueous extracts of root showed no inhibition towards *E. coli* (Table 3). Among the six different extracts of *S. mahagoni*, the ethanolic root extracts showed the lowest MIC values (mg/disc) viz: 1.1, 0.7, 0.9, 1.0 and 0.9 against *E. coli, P. vulgaris, P. aeruginosa, S. aureus* and *B. subtilis* respectively. The MBC values of extracts are summarized in Table 4. Fabry et al. (1998) conducted an ethno pharmacological survey of six East African medicinal plants viz. *Entada abyssinica* (stem bark), *Terminalia spinosa* (young branches), *Harrisonia abyssinica* (roots), *Ximenia caffra* (roots), *A. indica* (stem bark and leaves), and *Spilanthes mauritiana* (roots and flowers) against 105 strains of bacteria and reported *H. abyssinica*, *A. indica* (leaves), and *S. mauritiana* (roots and flowers) had MIC and MBC values less than or equal to 8 mg/ml. Baswa et al. (2001), assessed the antibacterial activity of Neem (A. indica) seed oil *in vitro* against fourteen strains of pathogenic bacteria using tube dilution technique. It was observed that 21.42% of the pathogens were inhibited at 500 microl/ml, 71.42% at 125 microl/ml and 7.14% at 250 microl/ml of neem oil. The methanol extract of neem leaf was tested for its antibacterial, antisecretory and antihemorrhagic activity against multi-drug-resistant *Vibrio cholerae* and reported significant antibacterial activity of the extracts (Thakurta et al., 2007). The aqueous and alcoholic extracts of leaf, stem and root of *A. indica* tested in the present investigation was effective against all the five bacterial strains. The MIC values of the ethanolic extracts of the plant parts were found to be lower than the respective aqueous extracts. It was observed that 0.7 mg of leaf extract, 0.8 mg of root extract, 0.7 mg of stem extract, 1.0 mg of leaf extract and 0.9 mg of root extract per disc to be the lowest MIC value against *E. coli, P. vulgaris, P. aeruginosa, S. aureus* and *B. subtilis* respectively. The MBC values of each extracts are given in Table 4. No previous reports on the antibacterial activity of *N. alata* could be found in literature. The observations of the present investigation show the high degree of antibacterial efficacy of leaf stem and root extracts of *N. alata*. The aqueous stem extracts was found to be the most effective against all the bacterial strains. The MIC values of the aqueous stem extracts (mg plant extract/disc) against the five bacterial strains viz: *E. coli* (0.8 mg/disc), *P. vulgaris* (0.7 mg/disc), *P. aeruginosa* (0.7 mg/disc), *S. aureus* (0.8 mg/disc) and *B. subtilis* (0.7 mg/disc) was found to be the lowest among the three test plants. The MBC values of each extracts are depicted in Table 4. Our results are in agreement with earlier reports of Hiremath et al. (1996 and 1997), stated that the dicot plants are producing certain alkaloids which control the growth of microbial pathogens.

Conclusions

The antibacterial efficacy of the phytoextracts suggests the presence of high concentration of an active principle in the extracts and so the plants, *N. alata, A. indica* and *S. mahagoni* have high potential as a source of new antimicrobial agents for therapeutic use. Since the use of antibiotics is not only expensive but also develop drug resistance in bacteria, the extracts of the plants can be used to control the different bacterial diseases. The high degree of antibacterial activity seems to confirm the

Table 1. Antibacterial efficacy of leaf extracts of experimental plants.

Plants	Solvent	Concentration (%)	Zone of Inhibition in mm				
			E. coli	***P. vulgaris***	***P. aeruginosa***	***S. aureus***	***B. subtilis***
N. alata	Water	5	1.5 ± 0.01	1.3 ± 0.05	0	1.4 ± 0.03	1.21 ± 0.02
		10	2 ± 0.04	1.45 ± 0.01	0	1.5 ± 0.09	1.7 ± 0.12
		15	1.7 ± 0.03	2 ± 0.07	0	1.5 ± 0.03	1.0 ± 0.05
		20	1.5 ± 0.10	2.6 ± 0.11	1.5 ± 0.06	2 ± 0.05	1.3 ± 0.01
		25	0	0	1.6 ± 0.01	2.5 ± 0.15	1.4 ± 0.11
	Ethanol	5	3.5 ± 0.02	2.5 ± 0.05	1 ± 0.06	2 ± 0.16	1.8 ± 0.06
		10	4 ± 0.13	2 ± 0.01	0	3.75 ± 0.01	2.3 ± 0.01
		15	2.75 ± 0.17	3 ± 0.15	1.5 ± 0.12	6 ± 0.07	2.4 ± 0.23
		20	2.1 ± 0.05	4.5 ± 0.05	2 ± 0.014	7.5 ± 0.04	2.4 ± 0.09
		25	2 ± 0.08	1.5 ± 0.01	2.5 ± 0.03	7 ± 0.09	2.7 ± 0.03
A. indica	Water	5	1.2 ± 0.11	0	1.2 ± 0.15	0	1.0 ± 0.01
		10	1.51 ± 0.09	1.3 ± 0.01	1.3 ± 0.02	0	1.3 ± 0.14
		15	1.6 ± 0.03	1.37 ± 0.07	1.32 ± 0.07	1.4 ± 0.03	1.3 ± 0.08
		20	1.82 ± 0.01	1.41 ± 0.15	1.8 ± 0.16	1.6 ± 0.16	1.5 ± 0.14
		25	2.3 ± 0.13	1.7 ± 0.06	1.9 ± 0.17	1.91 ± 0.26	1.6 ± 0.03
	Ethanol	5	1.4 ± 0.12	1.3 ± 0.15	0	1.2 ± 0.27	1.1 ± 0.16
		10	1.8 ± 0.03	1.41 ± 0.16	1.2 ± 0.16	1.5 ± 0.01	1.23 ± 0.20
		15	1.9 ± 0.09	1.63 ± 0.15	1.31 ± 0.06	1.51 ± 0.08	1.42 ± 0.02
		20	2.5 ± 0.04	1.9 ± 0.01	1.46 ± 0.17	1.7 ± 0.34	1.5 ± 0.01
		25	2.6 ± 0.16	2.5 ± 0.16	1.7 ± 0.09	1.81 ± 0.30	1.65 ± 0.18
S. mahagoni	Water	5	0	1.0 ± 0.18	0	0	0
		10	1.2 ± 0.02	0	0	1.2 ± 0.09	0
		15	1.2 ± 0.06	1.4 ± 0.04	1.3 ± 0.05	1.31 ± 0.14	1.2 ± 0.09
		20	1.6 ± 0.09	1.4 ± 0.07	1.7 ± 0.17	1.4 ± 0.18	1.35 ± 0.24
		25	1.9 ± 0.15	1.6 ± 0.30	1.91 ± 0.23	1.61 ± 0.09	1.4 ± 0.15
	Ethanol	5	1.4 ± 0.21	-0.07	1.1 ± 0.26	1.0 ± 0.01	1.0 ± 0.09
		10	1.5 ± 0.20	1.16 ± 0.17	1.4 ± 0.21	1.23 ± 0.03	1.23 ± 0.15
		15	1.62 ± 0.07	1.61 ± 0.01	1.6 ± 0.09	1.42 ± 0.07	1.7 ± 0.07
		20	1.69 ± 0.01	1.8 ± 0.15	1.9 ± 0.03	1.67 ± 0.35	1.9 ± 0.09
		25	1.8 ± 0.07	2.1 ± 0.11	2.3 ± 0.03	1.90 ± 0.01	2.1 ± 0.31

Values are means ± standard errors (SE) of measurements taken in triplicates (n = 3) and $P < 0.05$. The values of negative control were subtracted from the values of samples and the corrected values are given as zone of inhibition.

Table 2. Antibacterial efficacy of stem extracts of experimental plants.

Plant	Solvent	Concentration (%)	Zone of Inhibition in mm				
			E. coli	***P. vulgaris***	***P. aeruginosa***	***S. aureus***	***B. subtilis***
N. alata	Water	5	1.95 ± 0.04	1.35 ± 0.04	2.25 ± 0.09	1.5 ± 0.03	1.42 ± 0.11
		10	2 ± 0.01	1.5 ± 0.15	3 ± 0.32	2.25 ± 0.01	1.5 ± 0.01
		15	2.25 ± 0.13	1.75 ± 0.25	3.5 ± 0.05	4.25 ± 0.15	1.58 ± 0.09
		20	4.5 ± 0.17	4 ± 0.12	4 ± 0.41	9 ± 0.07	1.7 ± 0.31
		25	7 ± 0.09	3 ± 0.09	4.5 ± 0.09	10.5 ± 0.17	2.0 ± 0.04
	Ethanol	5	0	0	0	0	1.2 ± 0.09
		10	2 ± 0.01	0	0	1.5 ± 0.01	1.3 ± 0.15
		15	1.5 ± 0.06	1.2 ± 0.02	1.5 ± 0.04	1.7 ± 0.31	1.41 ± 0.09
		20	1.5 ± 0.11	1.2 ± 0.04	1.5 ± 0.01	1.3 ± 0.03	1.48 ± 0.21
		25	1.2 ± 0.09	1.5 ± 0.07	1.5 ± 0.31	1.25 ± 0.41	1.8 ± 0.09
A. indica	Water	5	0	1.2 ± 0.31	0	0	0
		10	1.5 ± 0.14	1.31 ± 0.36	1.5 ± 0.05	1.2 ± 0.09	1.2 ± 0.03
		15	1.5 ± 0.17	1.40 ± 0.02	1.53 ± 0.09	1.4 ± 0.43	1.26 ± 0.27
		20	1.7 ± 0.21	1.45 ± 0.09	1.7 ± 0.31	1.61 ± 0.23	1.5 ± 0.26
		25	1.9 ± 0.20	1.6 ± 0.03	1.8 ± 0.37	1.8 ± 0.26	1.82 ± 0.01
	Ethanol	5	1.3 ± 0.51	0	1.3 ± 0.05	1.34 ± 0.09	1.9 ± 0.23
		10	1.5 ± 0.05	1.4 ± 0.14	1.7 ± 0.14	1.51 ± 0.01	1.98 ± 0.16
		15	1.6 ± 0.54	1.6 ± 0.09	1.9 ± 0.07	1.71 ± 0.41	2.1 ± 0.12
		20	1.9 ± 0.41	1.82 ± 0.42	2.3 ± 0.17	1.8 ± 0.15	2.5 ± 0.09
		25	2.4 ± 0.48	2.1 ± 0.09	2.8 ± 0.09	2.3 ± 0.05	2.8 ± 0.01
S. mahagoni	Water	5	0	0	1.12 ± 0.31	0	0
		10	1.3 ± 0.01	0	1.3 ± 0.09	0	1.3 ± 0.31
		15	1.7 ± 0.21	1.3 ± 0.51	1.5 ± 0.56	1.3 ± 0.03	1.7 ± 0.12
		20	2.1 ± 0.20	1.6 ± 0.43	1.7 ± 0.04	1.61 ± 0.37	1.8 ± 0.06
		25	2.5 ± 0.29	1.9 ± 0.05	2.0 ± 0.08	1.7 ± 0.03	1.85 ± 0.32
	Ethanol	5	0	1.3 ± 0.41	1.3 ± 0.01	0	1.1 ± 0.09
		10	1.4 ± 0.06	1.5 ± 0.09	1.46 ± 0.14	1.56 ± 0.08	1.24 ± 0.24
		15	1.7 ± 0.15	1.8 ± 0.04	1.62 ± 0.34	1.61 ± 0.35	1.36 ± 0.09
		20	1.9 ± 0.21	2.1 ± 0.09	2.1 ± 0.18	1.9 ± 0.41	1.51 ± 0.31
		25	2.0 ± 0.26	2.5 ± 0.41	2.5 ± 0.01	2.1 ± 0.31	1.59 ± 0.09

Values are means ± standard errors (SE) of measurements taken in triplicates (n = 3) and $P < 0.05$. The values of negative control were subtracted from the values of samples and the corrected values are given as zone of inhibition.

Table 3. Antibacterial efficacy of root extracts of experimental plants.

Plant	Solvent	Concentration (%)	Zone of Inhibition in mm				
			E. coli	***P. vulgaris***	***P. aeruginosa***	***S. aureus***	***B. subtilis***
N. alata	Water	5	0	2 ± 0.09	1.5 ± 0.18	2 ± 0.09	0
		10	0	2 ± 0.45	1.5 ± 0.11	2 ± 0.25	0
		15	0	2.5 ± 0.34	1.45 ± 0.19	2 ± 0.09	1.24 ± 0.05
		20	1.5 ± 0.06	3 ± 0.03	2 ± 0.09	2.5 ± 0.45	1.32 ± 0.03
		25	1.75 ± 0.01	3 ± 0.09	1.5 ± 0.01	3 ± 0.51	1.5 ± 0.32
	Ethanol	5	0	1.5 ± 0.23	2 ± 0.05	3 ± 0.02	1.12 ± 0.41
		10	0	1.5 ± 0.21	2.5 ± 0.18	3.5 ± 0.09	1.32 ± 0.09
		15	2 ± 0.16	3.75 ± 0.09	3 ± 0.34	4 ± 0.17	1.5 ± 0.01
		20	2.5 ± 0.11	7 ± 0.04	4.7 ± 0.28	3.75 ± 0.36	1.7 ± 0.32
		25	3.25 ± 0.23	3 ± 0.32	5.75 ± 0.04	2.25 ± 0.05	2.2 ± 0.03
A. indica	Water	5	0	1.1 ± 0.43	1.4 ± 0.43	0	1.3 ± 0.14
		10	0	1.4 ± 0.09	1.7 ± 0.09	0	1.42 ± 0.23
		15	0	1.5 ± 0.41	1.9 ± 0.15	0	1.5 ± 0.27
		20	1.0 ± 0.01	1.5 ± 0.54	2.0 ± 0.26	1.3 ± 0.04	1.7 ± 0.09
		25	1.0 ± 0.43	1.9 ± 0.16	2.3 ± 0.54	1.5 ± 0.19	1.8 ± 0.01
	Ethanol	5	0	1.4 ± 0.10	0	1.0 ± 0.17	1.0 ± 0.02
		10	1.0 ± 0.15	1.6 ± 0.01	1.2 ± 0.01	1.5 ± 0.19	1.31 ± 0.26
		15	1.3 ± 0.02	1.9 ± 0.41	1.4 ± 0.19	1.7 ± 0.09	1.41 ± 0.24
		20	1.8 ± 0.16	2.0 ± 0.34	1.7 ± 0.01	1.9 ± 0.14	1.48 ± 0.04
		25	2.3 ± 0.05	2.1 ± 0.31	1.9 ± 0.09	2.5 ± 0.15	1.5 ± 0.45
S. mahagoni	Water	5	0	0	1.3 ± 0.19	0	0
		10	0	1.6 ± 0.09	1.7 ± 0.41	1.6 ± 0.18	1.1 ± 0.021
		15	0	1.8 ± 0.18	1.9 ± 0.16	1.7 ± 0.01	1.2 ± 0.12
		20	0	2.0 ± 0.11	2.3 ± 0.41	1.9 ± 0.36	1.34 ± 0.32
		25	0	2.6 ± 0.36	2.8 ± 0.09	2.3 ± 0.05	1.38 ± 0.09
	Ethanol	5	0	1.4 ± 0.45	1.13 ± 0.31	0	1.4 ± 0.32
		10	1.1 ± 0.03	1.5 ± 0.09	1.6 ± 0.09	1.5 ± 0.16	1.5 ± 0.04
		15	1.4 ± 0.09	1.8 ± 0.18	1.8 ± 0.03	1.7 ± 0.08	1.6 ± 0.07
		20	1.4 ± 0.07	2.1 ± 0.12	1.9 ± 0.56	2.0 ± 0.34	1.65 ± 0.35
		25	1.7 ± 0.13	2.3 ± 0.39	2.3 ± 0.41	2.3 ± 0.09	1.8 ± 0.01

Values are means ± standard errors (SE) of measurements taken in triplicates (n = 3) and $P < 0.05$. The values of negative control were subtracted from the values of samples and the corrected values are given as zone of inhibition.

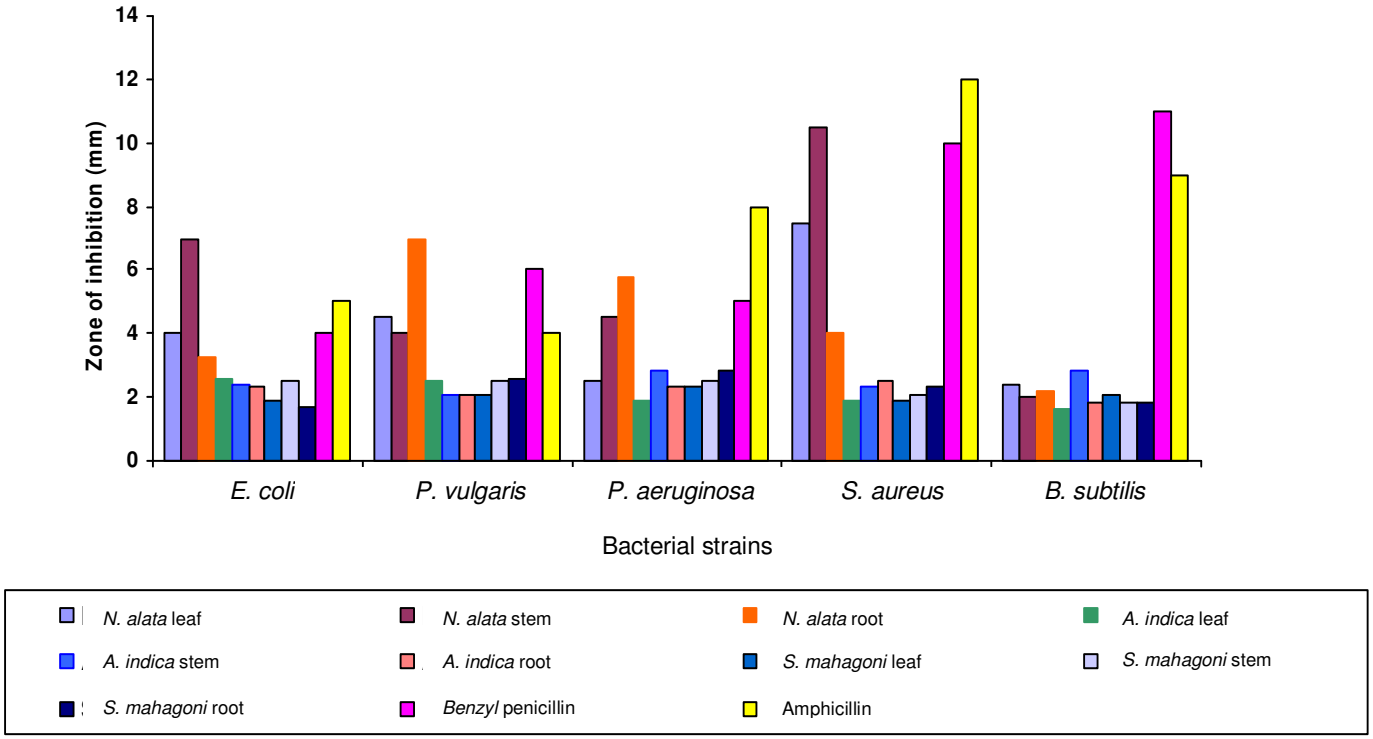

Figure 1. Comparison of antibacterial efficacy of aqueous/ethanolic extracts of test plants with 25% antibiotics.

Table 4a. MIC and MBC values (mg/ml) of experimental plant extracts against *N. alata*.

Microorganisms	*N. alata*											
	Leaf				Stem				Root			
	A		E		A		E		A		E	
	a	b	a	b	a	b	a	b	a	b	a	b
E. coli	1.8	1.9	0.9	1.1	0.8	0.9	2.1	2.3	1.7	1.9	0.9	1.1
P. vulgaris	2.0	2.1	0.9	1.2	0.7	0.9	1.9	2.0	1.9	2.0	0.7	0.8
P. aeruginosa	2.3	2.4	1.2	1.4	0.7	0.8	2.3	2.3	1.5	1.7	0.7	0.7
S. aureus	1.7	1.7	0.2	0.4	0.8	0.8	2.9	3.1	2.0	2.1	0.9	1.1
B. subtilis	1.5	1.7	1.8	2.0	0.7	0.9	3.0	3.1	1.8	2.0	0.8	1.0

A- Aqueous extract, E- Ethanolic extract, a- MIC, b- MBC.

Table 4b. MIC and MBC values (mg/ml) of experimental plant extracts against *S. mahogany*.

Microorganisms	*S. mahogany*											
	Leaf				Stem				Root			
	A		E		A		E		A		E	
	a	b	a	b	a	b	a	b	a	b	a	b
E. coli	2.3	2.4	1.4	1.6	2.8	3.0	1.3	1.4	3.5	3.6	1.1	1.4
P. vulgaris	2.6	2.9	0.8	1.1	2.5	2.7	1.2	1.4	2.1	2.5	0.7	0.9
P. aeruginosa	2.9	3.0	1.1	1.3	3.0	3.2	1.0	1.4	2.4	2.6	0.9	1.2
S. aureus	2.1	2.4	1.2	1.4	2.4	2.6	1.4	1.6	1.7	1.7	1.0	1.3
B. subtilis	2.9	3.2	1.4	1.6	1.9	2.2	1.2	1.4	1.8	1.9	0.9	1.2

A- Aqueous extract, E- Ethanolic extract, a- MIC, b- MBC.

Table 4c. MIC and MBC values (mg/ml) of experimental plant extracts against *A. indica*.

Microorganisms	*A. indica*											
	Leaf				Stem				Root			
	A		E		A		E		A		E	
	a	b	a	b	a	b	a	b	a	b	a	b
E. coli	1.9	2.0	0.7	0.8	2.3	2.5	0.8	1.0	2.7	2.9	1.2	1.4
P. vulgaris	1.5	1.7	1.2	1.3	2.9	3.2	1.2	1.4	1.7	1.9	0.8	1.0
P. aeruginosa	1.8	1.9	0.9	1.1	2.8	2.9	0.7	0.9	2.5	2.7	1.2	1.6
S. aureus	2.4	2.4	1.0	1.2	3.1	3.3	1.4	1.5	2.1	2.5	1.1	1.4
B. subtilis	2.6	2.8	1.0	1.4	2.9	3.1	1.2	1.5	1.8	1.0	0.9	1.2

A- Aqueous extract, E- Ethanolic extract, a- MIC, b- MBC.

traditional therapeutic claims of these plants. There is not much information available on the antimicrobial studies of *N. alata*. Further photochemical studies are required to determine the types of compounds responsible for the high degree of antibacterial efficiency of the plant.

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